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Real estate and construction sector investment logic on smart buildings

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Abstract of master's thesis

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Abstract

Smart buildings have been described as the embodiment of digitalisation in the real estate and construction (REC) sector. These buildings typically utilise a variety of interactive technical building systems, which operate autonomously through a smart grid without constant input from users. A clear definition of a smart building is, however, missing. Moreover, the added investment value of a smart building is not well measurable through the traditional real estate investment logic, which is based on the universal property value equation.

The objectives of this thesis are to review the definition of a smart building through the Smart readiness indicator (SRI) introduced by the European Commission, and to observe the added value of a smart building from the investment point of view. The research was accomplished through two research methods, a case study and interviews. In the SRI-methodology, the definition of a smart building and high SRI-score has been tied together. Therefore, in the case study the SRI-framework was applied to a multi-purpose campus building to evaluate, how well it takes into account the building's smartness. The interviews were carried out with Finnish REC-sector specialists to identify the key investment drivers, which are adding value to a smart building. Additionally, their effect on the investment logic was identified.

The case study showed that the smart readiness of the campus building was approximately 58% from the maximum obtainable SRI-score, but the framework did not take into consideration all the smart technical building systems implemented in the building. From the interviews it was discovered that the traditional methods of calculating a property's value, where the investment logic is based on the property level drivers of rental income, operating expenses and required yield, do not explicitly show the added investment value of a smart building. Instead, the added investment value of smart buildings is perceived to be related to the synergistic benefits in smart communities. Thus, a revision of the regular real estate property value equation and investment logic are considered as a prerequisite to be able to explicitly represent the added investment value of a smart building.

Keywords smart building, digitalisation, real estate and construction sector, technical building systems, investment logic, property value equation, smart readiness indicator

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Tiivistelmä

Älykkäät rakennukset kuvaavat digitalisaation ilmentymää kiinteistö- ja rakennus (KIRA) sektorilla. Nämä rakennukset käyttävät tyypillisesti monia vuorovaikutteisia taloteknisiä järjestelmiä, jotka toimivat itsenäisesti älykkään verkon kautta ilman käyttäjien ohjausta. Älykkäälle rakennukselle ei ole kuitenkaan vielä kehittynyt yleisesti hyväksyttyä määritelmää. Lisäksi älykkään rakennuksen lisäarvo ei ole mitattavissa perinteisen kiinteistöinvestointilogiikan kautta, joka pohjautuu yleiseen kiinteistön arvon laskukaavaan.

Tämän työn tavoitteena on tarkastella älykkään rakennuksen määritelmää Euroopan Komission ehdottaman 'Smart readiness indicator' (SRI) työkalun kautta sekä tunnistaa älykkään rakennuksen lisäarvo investointina. Tutkimus toteutettiin tapaustutkimuksen ja haastatteluiden avulla. SRI-metodologiassa esitetyn ehdotuksen mukaisesti korkea SRI-pistemäärä vastaa älykkään rakennuksen määritelmää. Sen takia SRI-kehikkoa sovellettiin monimuotoisen kampusrakennuksen älykkyyden arvioinnin tapaustutkimuksessa. Haastattelut toteutettiin suomalaisten KIRA-sektorin asiantuntijoiden kanssa. Tavoitteena oli tunnistaa älykkään rakennuksen investointiarvoa lisäävät tekijät sekä havainnoida tunnistettujen tekijöiden vaikutusta investointilogiikkaan.

Tapaustutkimus osoitti, että kampusrakennuksen älykkyysvalmius oli 58% määritellystä SRI-maksimiarvosta, mutta kehikko ei ottanut huomioon kaikkia rakennuksessa toteutettuja älykkäitä taloteknisiä järjestelmiä. Haastatteluissa havaittiin, että perinteisen kiinteistön arvon laskukaavan kautta ei ole mahdollista yksiselitteisesti osoittaa älykkään rakennuksen lisäarvoa, missä vuokratuotto, kiinteistökustannukset ja tuottovaatimus mittaavat investointia kiinteistötasolla. Sen sijaan älykkään rakennuksen lisäarvon havaittiin liittyvän älykkään yhteisön synergian tuottamaan hyötyyn. Näin ollen perinteisen kiinteistön arvon laskukaavan ja kiinteistöinvestointilogiikan muuttaminen havaittiin edellytykseksi älykkään rakennuksen lisäarvon yksiselitteiselle perustelulle.

Avainsanat älykäs rakennus, digitalisaatio, kiinteistö- ja rakennussektori, talotekniset järjestelmät, investointilogiikka, kiinteistön arvon laskukaava, smart readiness indicator

Foreword

This Master's thesis has been conducted as part the RealGO-project between March and September 2018. RealGO is a project founded by STEK ry, STUL ry, Foundation for Quality of Construction Products and Aalto University. The project was carried out in interdisciplinary cooperation between Aalto Real Estate Business Unit, Aalto HVAC Team, Aalto Computer Science, Aalto CRE (Campus and Real Estate) and Aalto IT. The aim of the project was to develop new approaches for the building and construction business that enhance the use of digital solutions.

I want to thank both my thesis supervisor Professor Seppo Junnila and the thesis advisor D.Sc. Antti Säynäjoki for providing me guidance and invaluable tips throughout the research process. Additionally, I would like to thank the Aalto REB research group for sharing their knowledge from the field of real estate business.

The most I want to thank my awesome family who has supported me through the journey, which I started along with my studies as part of the Mechanical Engineering Department at Aalto University in 2012. Today on my 25th birthday, it is quite exactly six years, when I took the first steps as a university student. The time spent at the university has been challenging but rewarding mostly due to the incredible student community at the Otaniemi campus area.

Graduating from the Aalto University School of Engineering would not have however been possible without the invaluable support of my sister, Mira, who always encouraged and believed in me during the life we got to share together. This thesis is dedicated to my sister, having my greatest appreciation of this achievement, but who is not today here with me to share the honour.

Otaniemi 9.9.2018

Eerika Janhunen

Contents

Abstract

Tiivistelmä

Foreword ... i

Contents ... ii

Abbreviations ... iv

Table of figures ... v

Table of tables ... vi

1 Introduction ... 1

2 Digitalisation in the real estate and construction sector ... 4

2.1 Recent digitalisation in the industry ... 4

2.2 A smart building ... 7

2.2.1 Smartness indicator ... 8

2.2.2 Smart grid ... 14

3 Investment characteristics in the real estate and construction sector ... 17

3.1 Property investor types and characteristics ... 17

3.2 Investment logic in the real estate business ... 20

3.2.1 Investment strategies ... 21

3.2.2 Investment drivers ... 24

4 Research methodology ... 27

4.1 A case study ... 28

4.2 Interviews ... 28

5 Research process ... 29

5.1 Performing a streamlined smart readiness indicator assessment for a pilot case building ... 29

5.1.1 A multi-purpose campus building ... 29

5.1.2 A streamlined smart readiness indicator assessment ... 31

5.2 Preparing and conducting semi-structured interviews with representatives from companies in the real estate and construction sector ... 34

5.2.1 The selection of the interviewees ... 35

5.2.2 The structure of the semi-structured interviews ... 36

6 Results ... 39

6.1 The smart readiness of the multi-purpose campus building ... 39

6.1.1 The final score ... 39

6.1.2 Domain-based scores ... 40

6.2 The investment logic on smart buildings ... 43
6.2.1 Decreased operating expenses ... 43
6.2.2 Increased rental income ... 45
6.2.3 Decreased required yield ... 46
7 Discussion ... 48
7.1 The smart readiness indicator as a smart building indicator ... 48
7.1.1 Assessing the smart readiness indicator final score of the multi-purpose campus building in real-life context ... 48
7.1.2 Defining the definition of a smart building ... 53
7.2 Evaluating the added investment value of a smart building through the identified investment logic ... 54
7.2.1 The key investment drivers adding value to a smart building ... 54
7.2.2 The investment strategies adding value to a smart building ... 57
8 Conclusion ... 61
9 Further Research ... 62
References ... 64
List of appendixes ... 70

Abbreviations

ACRE	Aalto Campus and Real Estate
BACS	Building Automation and Control System
BREEAM	Building Research Establishment Environmental Assessment Method
EC	European Commission
EU	European Union
DE	Dynamic Building Envelope
DER	Distributed Energy Resource
DH	District Heating
DHW	Domestic Hot Water
DSM	Demand-Side Management
EG	On-site Renewable Energy Generation
EGI	Effective Gross Income
EPB	Energy Performance of Buildings
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
EU	European Union
EC	European Commission
EC DG	European Commission Directorate-General
EV	Electric Vehicle
4IR	Fourth Industry Revolution
GDP	Gross Domestic Product
HVAC	Heating, Ventilation and Air Conditioning
IAQ	Indoor Air Quality
ICT	Internet and Communication Technology
IoT	Internet of Things
LEED	Leadership in Energy and Environmental Design
MC	Monitoring and Control
MV	Mechanical Ventilation
NOI	Net Operating Income
nZEB	nearly Zero Energy Buildings
PGI	Potential Gross Income
PropTech	Property + Technology
REC	Real Estate and Construction
REHVA	Federation of European Heating, Ventilation and Air Conditioning Associations
ROA	Real Options Analysis
SRI	Smart Readiness Indicator
SRT	Smart Ready Technologies
TBS	Technical Building Systems
TES	Thermal Energy Storage

Table of figures

Figure 1. U.S based report of the relative digitalisation among the different industry sectors (McKinsey & Company, 2015) 5
Figure 2. Direct property holdings of 30 biggest property investors in Finland (KTI Finland, 2018b) 18
Figure 3. Property investment strategies in the risk-return spectrum (Formigle, 2016) 24
Figure 4. The winning design of the case building from outside (Verstas Architects, 2013) 30
Figure 5. The winning design of the case building from inside (Verstas Architects, 2013) 30
Figure 6. The framework of the investment drivers on environmental sustainability (Falkenbach et al., 2010) 55

Table of tables

Table 1. The functionality levels of the sub-service of heat emission control under the domain of heating (Verbeke et al., 2017) 11
Table 2. The functionality levels of the sub-service of air temperature control under the domain of heating (Verbeke et al., 2017) 12
Table 3. Domain-level impact weighting table, equal weighting (Verbeke et al., 2017) 13
Table 4. Example of SRI-scores and the heuristic scale (Verbeke et al., 2017) 14
Table 5. Characteristics of the multi-purpose campus building (Janhunen, 2018) 31
Table 6.The interview information of the REC-sector specialists (Janhunen, 2018) 35
Table 7. The final scores of the SRI-assessment of the case building (Janhunen, 2018) 39
Table 8. SRI-scale applied in the rating (Verbeke et al., 2017) 40

1 Introduction

Digitalisation is defined as the biggest single trend affecting the world economy, society and environment and it is touching every industry sector in today's business (Iyer and Venkatraman, 2015). Some industries have managed to take the full benefit of digitalisation, whereas some industries have been lacking behind the development. The haves of digitalisation have built their entire business on digital devices and services (McKinsey & Company, 2015), and today the traditional real estate and construction (REC) sector have started to adapt the new rules of strategy into their business (KPMG, 2017).

In the REC-sector, digitalisation is redefining the built and digital spheres and merging them into one coherent environment, and a smart building has been introduced as one embodiment of it in the traditional sector (Säynäjoki *et al.*, 2017). According to Säynäjoki et al. (2017), smart buildings enable the forming of a new type of platform ecosystem in the sector and it provides an opportunity for increasing the value of external data distribution in the form of smart communities and smart cities. However, the value of a smart building has remained as undefined, and according to Säynäjoki et al. (2017), the reason for it is the lack of the recognised value of the external data. Additionally, one reason for the undefined value might result from the generally missing definition of a smart building, which causes confusion around the term. Therefore, the European Union has introduced one proposal for the definition of a smart building.

The EU is targeting in significant energy efficiency improvements in the built environment in the forthcoming years, and the potential of digitalisation in achieving the targets through the concept of a smart building has arisen a great interest among the policymakers. As a result, the European Commission has through the amending proposal of the Energy Performance of Buildings Directive (EPBD, 2010) introduced a smart readiness indicator (SRI), purposed to efficiently evaluate the smart readiness of buildings and provide an universal definition of a smart building. The EU legislation can be seen as one external driver towards smarter buildings. From the EU point of view, the value of the concept has been found around the energy efficiency theme and through the SRI, the goal is to increase the general awareness around smart buildings, but also to support real estate investments therein (Verbeke *et al.*, 2017). From the investment point of view, the energy efficiency aspect does not, however, provide enough evidence to start investing in smart buildings. The investors in the REC-sector have not yet internalised the property value of a smart building and therefore, the industry in general has not yet developed its business to completely support digitalisation. The key value of a smart building as a property investment seems to be hidden, and the definition of the concept is not explicit for the stake- and shareholders in the sector.

The potential of digitalisation in the REC-sector, however, exists. The sector is undoubtedly one of the key players regarding the world's economy, society and environment (INREV, 2013). In Europe, the commercial real estate employs more people than the automotive and telecommunications sectors combined (European Real Estate Forum, 2018). In Finland, the built environment comprises 20% of the national gross domestic product (GDP), and 80% of the national capital (ROTI, 2017). Therefore, the change process that is approached through digitalisation in the REC-sector can be predicted to have an enormous influence in all ways.

The change process that is in general approached through digitalisation, is also known as the fourth industry revolution (4IR), where the connected devices, shared information and digital network are predicted to change the nature of built environment (KPMG, 2017). As a result of the 4IR, the concept of a building we recognise today will change and it seems likely that a building is becoming more like a service than a solid construction in the future. The redefinition of the concept will affect the real estate business through the changed value of buildings and it will affect the nature of the investment drivers in the field. (Bailey and Smith, 2017)

Today, the property value of a smart building is possible to validate through the energy efficiency activities, but the other drivers directing the investment logic on smart buildings have not yet been clearly specified in the REC-sector. Therefore, the aim of this study is to observe the meaning of the concept of a smart building through the SRI introduced by the EC, but also to identify the property value of a smart building. The added investment value of smart buildings is observed through the key drivers directing the investment logic in the real estate business and the objective is to discover how smart buildings affect the regular real estate investment logic applied in today's REC-business.

The research objectives are approached through two research question. The preliminary research question approaches the objective from a case study perspective and the aim of the study is to validate the definition of a smart building provided through the smart readiness rating system of SRI. The preliminary research question supports the secondary research question, which approaches the primary objective of this thesis, the investment logic on smart buildings. From the objectives of this thesis, the following research questions have been formed:

1. How smart (ready) is a multi-purpose campus building?
2. How smart buildings affect the real estate investment logic?

Regarding this research, digitalisation is covered from a smart building point of view in the REC-sector outlining the other digital development in the field outside of the scope. Additionally, the investment logic is focused on properties as an investment, excluding the other investment assets in the real estate business from the research.

The research will be comprised of two main sections, including the literature review and the empirical research. Through the literature review, the main objectives of this study are approached from a theory based and up-to-date research point of view in the REC-sector. Chapter 2 introduces the recent digitalisation in the REC-sector and the concept of smart building is further studied in Chapter 2.2. In Sub-chapter 2.2.1, the methodology behind the SRI-framework is further elaborated. The aim of the sub-chapter is to provide the information that is required to understand the empiric research process behind the case study presented in the later chapters. In Chapter 3, the general investment characteristics in the REC-sector are approached. In the sub-chapters, the property investor types and characteristics are introduced, and the universal investment logic in the field is explored through the identified investor investment strategies and key investment drivers.

The empirical research starts from Chapter 4. In Chapter 4, the methodology of the chosen research methods is presented and reasoned, and in Chapter 5 the research process is introduced in a written form. The empirical research in this thesis is comprised of two research methods, where both of them tackle one of the research questions. The preliminary research question "How smart (ready) is a multi-purpose campus building?" is approached through the case study, where the SRI-framework is applied in a modern campus building. The primary research question "How smart buildings affect the real estate investment logic?" is investigated through the semi-structured interviews, where the Finnish REC-sector specialists are interviewed. The results found from the research are exhibited in Chapter 6, and they are further discussed in Chapter 7. In Chapter 8, the researcher concludes the research and presents the main findings. In the last chapter of this thesis, Chapter 9, the researcher provides the further research suggestions.

2 Digitalisation in the real estate and construction sector

The industry companies today are on the journey from digitalisation 1.0 to digitalisation 2.0. In the model introduced by Iyer and Venkatraman (2015), digitalisation 1.0 represents the first era of digitalisation in industry business, where the business value has lied in smart products and services, which are able to generate data about their users in various settings. The data collected have been utilised remotely to modify these products and to improve the customer experience, but the data has been applied only within one's own business boundary. In digitalisation 2.0, the customer needs are according to Iyer and Venkatraman (2015) fulfilled in cooperation across the business and organisational boundaries through the exchange of data gathered by smart products and services. The real disruptions and value shifts of digitalisation is estimated to lie in digitalisation 2.0 instead of digitalisation 1.0. (Iyer and Venkatraman, 2015)

According to Säynäjoki et al. (2017), the real opportunity of digitalisation in the real estate and construction (REC) sector is behind the huge amount of shared data that is available for organisations. In the future, the data gathered and applied in a corporate and external level in the forms of smart communities and cities, for instance, can enable the increase of the value of the distributed data. Hereby, by reflecting to the model provided by Iyer and Venkatraman (2015), these smart communities and cities, which can be seen as the outcome of the connected smart buildings, are an example of digitalisation 2.0 in the REC-sector. Until today, the full potential of digitalisation has, however, remained unreached in the field, even though recently some slight attitudinal change have arisen within the sector (Halmetoja, 2017). The point where the digitised products and their services are merged on a shared platform and the customer needs are met in cooperation over the business boundaries, is not yet reality in the REC-sector. (Säynäjoki *et al.*, 2017)

A smart building can be recognised as a conceptualised version of the connected building and similarly as one example of the embodiment of digitalisation in the REC-sector. As the outcome of digitalisation, smart buildings seem to represent the value shifts in the REC-sector, as well as the revision of the concept of traditional buildings. (Säynäjoki *et al.*, 2017) Nevertheless, in today's REC-business, the value of digitalisation has not reached a common knowledge among the stake- and shareholders. Therefore, the recent digitalisation in the REC-sector as well as the conceptualised outcome of it, a smart building, are observed in the chapter of this thesis.

2.1 Recent digitalisation in the industry

Already for years, industry companies have been able to collect data from the usage of their digital devices. Along with digitalisation 1.0, the value of digitalisation has been generated through the data based and tailored customer experience. Smart products have affected the conventional business actions and operations in all industry levels through the internet of things (IoT), where the change has added value to the business. (Iyer and Venkatraman, 2015) A value-based definition of digitalisation is provided by IT glossary Gartner, which is consistent with the maturity model presented by Iyer and Venkatraman (2015):

Digitalization is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business. (Gartner, 2018)

The business models in all industry levels have been somewhat redefined already as part of digitalisation 1.0, when the digital devices and their cloud-based interfaces have been applied as part of the service environment (Iyer and Venkatraman, 2015). The digitalisation of industries and companies have nevertheless happened unequally, and relatively low digitalisation have concerned especially industries, which are both highly labour-intensive and localised, such as the real estate and construction sector (Bughin *et al.*, 2017). The relative digitalisation among the different industries in U.S according to a report by McKinsey & Company (2015) is shown in Figure 1.

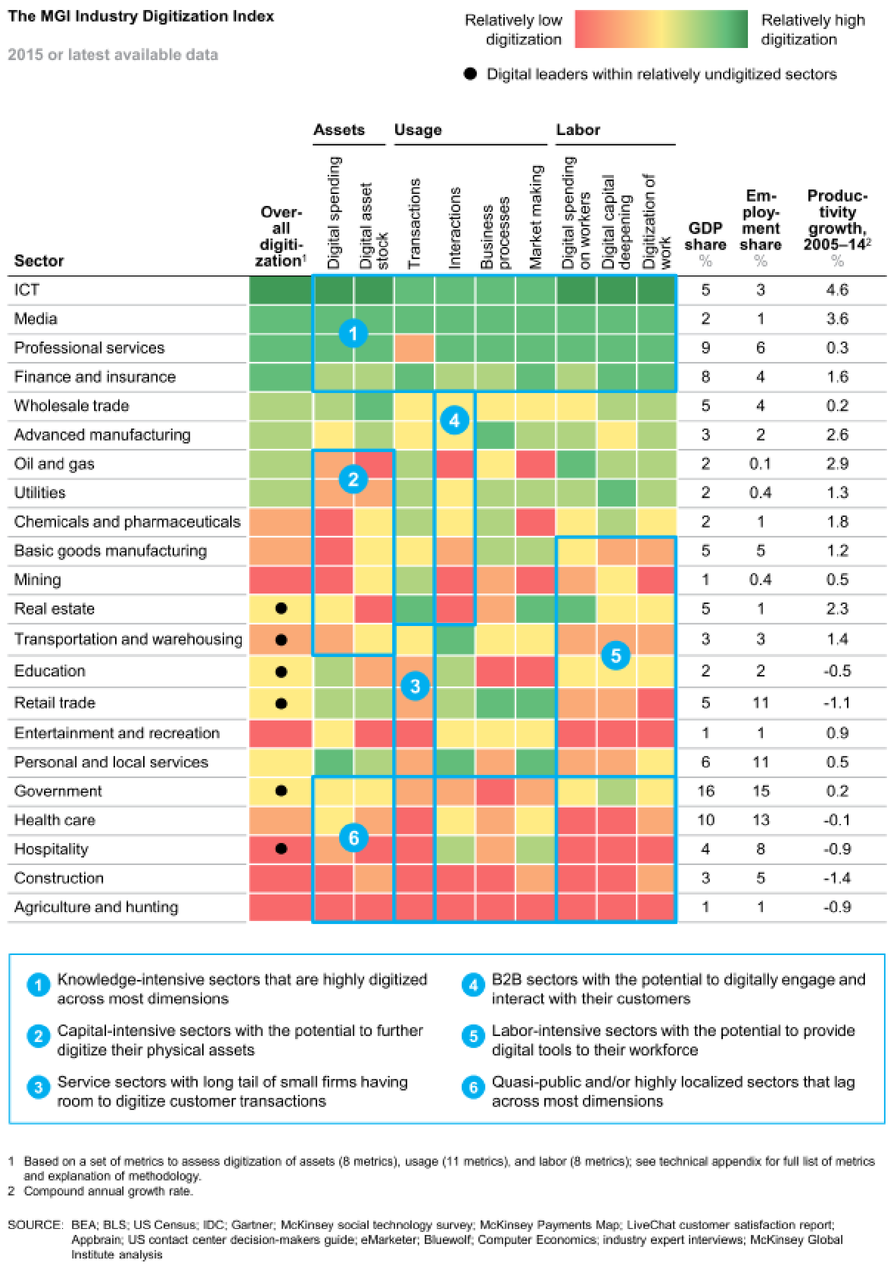


Figure 1. U.S based report of the relative digitalisation among the different industry sectors (McKinsey & Company, 2015)

Based on the digitalisation index shown above, the Internet and Communication Technology (ICT) based industries, for instance, represent the haves of digitalisation, where modern companies, such as Uber, Airbnb and Alibaba have based their business strategy purely on top of a platform and scaled their business fast with low costs (McKinsey & Company, 2015; Bughin *et al.*, 2017). Such growth has not been possible before digitalisation, where the physical infrastructure and assets have been an obstacle for a rapid scale up of the business (Van Alstyne *et al.*, 2016). In general, the haves of digitalisation are identified as modern business players, whose business opportunity is built to bridge the gap between physical and digital spheres (Halmetoja, 2017).

Merging the physical and digital spheres into one shared environment is already changing the way we live, work and interact in today's society. The REC-sector have however struggled in revising their business strategies to support the development of the digitising society. (KPMG, 2017) The ideology of the combined business boundaries of digitalisation 2.0 (Iyer and Venkatraman, 2015) have perhaps been seen as offensive in the sector, where the boundaries as well as the information flow have traditionally been tightly closed within one's own business boundary (Halmetoja, 2017).

Bridging the gap between digital and physical environments

The potential of digitalisation is clearly accepted in the REC-sector, but the adaption of it has strongly lagged behind compared to the other industries, as it was shown above in Figure 1. In a recent study carried out by KPGM (2017), it was found that only a small percentage of the real estate organizations have revised their business strategy to support digitalisation in general. The study covered over 330 real estate decision makers worldwide, and only 34% of the respondents had an enterprise-wide business strategy for digitalisation. However, 92% of them thought, that digital and technological change will have a great impact on their business. According to the study (KPGM, 2017), it seems that one challenge in the sector is to bridge the gap between digital and built environment and bring the service industry into the field.

Some digital development in the REC-sector have however happened through technology orientated entrepreneurs who have along with digitalisation 1.0 entered the field aiming to bridge the gap between built and digital environment. The newcomers seek for fulfilling the increased interest among the users regarding the connectivity, adaptability, convenience as well as flexibility of leases in a property business. Through service based technical devices, such as learning thermostats, these entrepreneurs have thrived for merging the built and digital environments in the building business (Iyer and Venkatraman, 2015). (KPGM, 2017).

These technology-orientated entrepreneurs have become the symbol of PropTech in the REC-sector, referring to the integration of the property and technology business. The awareness of the concept has increased in recent years, which indicates a growing acceptance and adaption of digitalisation in the REC-sector in general. The ambassador of PropTech, Atlas International director, James Dearsley, has provided a widely accepted definition of the concept:

Proptech is one small part of a wider digital transformation in the property industry. It considers both the technological and mentality change of the real estate industry, and its consumers to our attitudes, movements and transactions involving both buildings and cities. (Dearsley, 2017)

PropTech seems to somewhat symbolise the change process caused by digitalisation 1.0 in the REC-sector (Lecamus, 2017), but the next phase of digitalisation, digitalisation 2.0, can be expected to take the industry's digitalisation into the next level. According to Iyer and Venkatraman (2015), Google has already put digitalisation 2.0 into practice and experimented the concept of a connected building. In the concept, Google has merged the digital devices, shared platform and open interfaces across the business boundaries in the closed environment of a home. In cooperation with the learning Nest thermostats, today part of Google, and Android based embedded operating platform, Brillo, Google has opened up its interfaces to connect and communicate with other devices both inside and outside the ecosystem created in a building environment (Iyer and Venkatraman, 2015). Hypothetically, the next step for Google would be to connect these operating environments on a community of a connected platform ecosystem. (Iyer and Venkatraman, 2015)

2.2 A smart building

The concept of a building has developed over time along with the world society, economy and environment. Today the concept of a connected building represents the ideology behind the 'future buildings'. The initial idea of the 'future building' however, originates longer than three decades from now, when the term intelligent building (IB) has been conceptualised. Twenty years ago, the term was used to provide a definition for future buildings, which effectively manage their resources and flexibly answer the changing needs of an occupant (Kroner, 1997). In 1997, Clements-Croome has in his article defined IB as a property, which helps an organisation to fulfil its objectives by facilitating the management of business, space and building and thereby increases the effectiveness and efficiency of the organisation (Clements-Croome, 1997). Seemingly, the business value-based ideology behind the concept of a future building has remained similar from the 20th century to the 21st century.

Buildings today are complex units of structures, systems and technology, where the various pieces are connected in an integrated, dynamic and functional way to achieve the requirements the world society, economy and environment set up for the built environment (Building Efficiency Initiative, 2011). Due to the rising awareness of the sustainability issues today, buildings in the future must fulfil the mission of improving the energy efficiency and minimizing the carbon impact to mitigate the environmental impact caused by the built environment today. At the same time, the performance of buildings must rise in terms of connectivity and smart systems, which optimise the efficient operation of buildings. (JLL, 2013) The concept of a smart building can be seen to fulfil the characteristics of the 'future building', where the smartness of the building refers to the building's ability to leverage its services at the lowest possible cost and environmental impact over its lifecycle. At the same time, a smart building provides a comfortable, healthy, safe and productive indoor environment for its occupants. (Building Efficiency Initiative, 2011).

In the 21st century, the EU-level legislation supports strongly the transition towards smart buildings. A smart building has been identified as the enabling concept for achieving the EU-level energy efficiency goals of the building stock. EU has committed to nearly zero-energy buildings (nZEBs) by 2020, when all new buildings are required to perform nearly zero or a very low amount of energy during their lifecycle. By 2030, the EU has committed to cut the CO2-emmissions by minimum 40%, and by 2050, the building stock in the EU shall be fully decarbonised. (European Commission, 2018) These goals are stated in the Energy Performance of Buildings Directive (EPBD, 2010) and in the proposal of amending the directive (amending EPBD, 2016). Regarding the concept of a smart building, the potential of digitalisation is seen to exist in using the ICT-devices in the control of technical building services to improve the overall energy efficiency of buildings (Accenture, 2011).

The value of smart buildings from the EU-perspective is strongly related to the energy efficiency aspect, and the potential of digitalisation and ICT in achieving the short- and long-term goals by 2020, 2030 and 2050 is promoted through the directives. To promote the concept of a smart building more efficiently, in the amended EPBD (2016), a framework for the efficient evaluation of the buildings' smartness was introduced. Through the proposed smartness indicator, the EU pursues to encourage the use of ICT and smart technologies to ensure that the buildings operate efficiently, but also to develop an explicit rating system for evaluating the buildings' readiness for smart performance (amending EPBD, 2016). Through such rating system, it is ideally possible to identify the technical building systems (TBS) categories, where the expected results for achieving the energy efficiency goals in the EU have not been delivered as planned. (amending EPBD, 2016)

2.2.1 Smartness indicator

One of the key focus areas in the content of the amended EPBD (2016) is to better identify the potential of smart ready technologies (SRT) in terms of energy savings in a cost-effective way, as well as proving comfort and building adjustment to answer the needs of the users (European Commission, 2016). In the original EPBD (2010), the potential of ICT was already considered, but amending the directive was intended to provide additional support by introducing the Building Automation and Control Systems (BACS) for proactive building maintenance, as well as the 'smartness indicator' to assess the technical readiness of the building (Verbeke *et al.*, 2017). The aim of introducing a such smartness indicator is to raise awareness on the benefits regarding SRT and their functionalities, as well as encourage investments therein. Ideally, the indicator would promote the integration of the energy efficient ICT-based solutions into buildings, as well as assist in designing and developing more healthy and comfortable buildings. Additionally, the indicator is expected to facilitate the integration of the renewable energy sources (RES) into the TBS. (Verbeke *et al.*, 2017)

To create such a smartness indicator, a study team (Verbeke *et al.*, 2017) was assigned by the European Commission Directorate-General (EC DG) Energy in 2017 to define a smart readiness indicator (SRI) methodology as a preparatory study for the commission. In the context of this literature review, the methodology applied in the interim report (Verbeke *et al.*, 2017) of the SRI-study is here used as a reference to the SRI-framework. Today, the second progress report has been published (Verbeke *et al.*, 2018) and the third and final report of the technical study for setting up such smartness indicator for buildings, is published in the end of August 2018. The final methodology of the SRI, including an authorised definition and calculation methodology, as well as the developing and implementing acts for detailing the technical modalities for an effective implementation of the framework, is planned to be adopted by the end of the year 2019. (Rey García, 2018)

In this sub-chapter, the definition of a smart building is further elaborated based on the SRI-framework presented in the initial report (Verbeke *et al.*, 2017). Here, the SRI-methodology is explicitly presented as well as the evaluation system of such smart readiness assessment. The framework will be applied in a case study as part of the empirical research later in this thesis, and therefore the theory is here clarified explicitly.

Smartness and a smart building

Smart buildings are acknowledged as the key enablers of the future energy systems in the built environment. In the future the renewable energy sources, distributed supply, energy flexibility and production, and demand side management, for instance, are part of the future buildings (European Commission, 2016). Despite the fact that the key enablers of the themes behind 'smartness' in relation to buildings have been identified, the universally accepted definitions for such buildings is still missing. (Ghaffarianhoseini *et al.*, 2016). Therefore, one goal of the SRI-study was to introduce definitions for 'smartness' and 'a smart building'. The study team has introduced the following definitions:

Smartness refers to the capability of a building or its systems to sense, interpret, communicate and actively respond in an efficient manner to the changing conditions, which are introduced by demands of the building occupant, the operation of technical building systems or the external environment (including energy grids). (Verbeke *et al.*, 2017)

A smart (ready) building is a building with a high SRI score. (Verbeke *et al.*, 2017).

Smart ready technologies and services in a technical building system

The SRI can be seen to be based on SRT and their services in a smart building environment, where the services apply the technologies to satisfy the user needs or to fulfil the demand from the occupant of the building. SRT is the foundation for the services to be implemented in buildings, where the services and their sub-services utilise those technologies. The term smart in this context refers to the optimisation, interaction with occupants and the building's ability for being interoperable and adaptive. Verbeke et al. (2017) defined a service in a building environment as a function or an aggregation of functions delivered by one or more technical component or systems. The services perform a business purpose for a REC-sector stakeholder and can range from simple services to complex unities. Smart ready services are defined in the SRI-methodology in a technology neutral way. (Verbeke *et al.*, 2017)

The definition for the TBS utilised as part of the SRI-methodology is applied from the EPBD (2010), where it is defined as:

A technical equipment for the heating, cooling, ventilation, hot water, lightning or a combination thereof, of a building or building unit. (EPBD, 2010)

From the original definition, a developed version to cover also the building automation and control, on-site electricity control and on-site infrastructure for electro-mobility is proposed in the amended EPBD (2016). In the context of the SRI-study, the definition of the TBS is extended to consider the connection of the building to the other infrastructures like electricity, water and waste. Additionally, in the SRI-methodology the study team has identified and characterised the SRT together with the smart ready services and have proposed functionalities, which these technologies can provide to a building and its occupants. The catalogue of services is structured by a set of domains, and the smart ready services are as part of the SRI assessed based on their functionality level and their impacts on the building performance. (Verbeke *et al.*, 2017)

Mapping the smart ready services

The technical building systems are categorised in align with the definition provided by the SRI-study team into 10 main domains. The domains contain a set of suitable smart ready technologies, which can improve the services' operations and energy efficiency. Based on the preliminary proposal, a streamlined version of the SRI-methodology is introduced, where 50 sub-services were identified. These services were selected based on their actionability today, as well as based on their reasonable confidence when assessing their attribution of impacts to the identified functionality levels. The 10 domains and their possible abbreviations in the SRI-methodology are presented in the following:

1. Heating
2. Cooling
3. Domestic Hot Water (DHW)
4. Mechanical Ventilation (MV)
5. Lighting
6. Dynamic Building Envelope (DE)
7. On-site Renewable Energy Generation (EG)
8. Demand Side Management (DSM)
9. Electric Vehicle Charging (EV)
10. Monitoring and Control (MC)

(Verbeke *et al.*, 2017)

The main domain of heating, as an example, includes a service of the "heat control", which is divided into the smart services based on the control on either the demand or supply side. The study team has identified seven sub-services for the heat control on the demand side, and five sub-services for the heat control on the supply side. All the services in the methodology are defined in a technology neutral way. (Verbeke *et al.*, 2017)

The reasoning and the assessment of the smart services in the SRI-framework happens in most cases based on the international technical standards, which are also mentioned in the SRI. BACS (Building Automation and Control System) control functions happens based on SFS-EN 15232-1 (2017), lighting control systems based on EN 15193-1:2017 (SFS-EN 52000, 2017) and smart grid is based on the standard IEC 62559-2:2015 (Verbeke *et al.*, 2017), to mention a few examples. In the cases, where a standard does not support, or supports only a part of the service identified, such as the services under the domain electric vehicle charging, the evaluation is made based on the inspector's expertise or market knowledge. (Verbeke *et al.*, 2017)

Evaluating the smartness of the sub-services

The evaluation of the sub-services is completed by using the chosen functionality levels. In the streamlined version of the SRI-methodology that is applied in this research, the maximum functionality of a service is identified on the level 4, referring to a developed smart service, and the level 0 indicates a non-smart service. For each sub-service, a functionality level that responds the best the smartness of the service is chosen. The higher the score is, the smarter the building is evaluated based on the SRI-framework. (Verbeke *et al.*, 2017)

In the case of the heating domain in the streamlined SRI-methodology, the service "heat control" on the demand side and its sub-service "heat emission control", would be divided into four levels according to the framework, where the functionality levels are:

Level 0: No automatic control
Level 1: Central automatic control (e.g. central thermostat)
Level 2: Individual room control (e.g. thermostatic valves, or electronic controller)
Level 3: Individual room control with communication between controllers and to BACS
Level 4: Individual room control with communication and presence control

In Table 1 below, the functionality levels of the sub-service "heat emission control" are exhibited as they are stated in the streamlined SRI-framework. (Verbeke *et al.*, 2017)

Table 1. The functionality levels of the sub-service of heat emission control under the domain of heating (Verbeke et al., 2017)

Domain	Sub-Service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4
Heating	Heat emission control	No automatic control	Central automatic control (e.g. central thermostat)	Individual room control (e.g. thermostatic valves, or electronic controller)	Individual room control with communication between controllers and to BACS	Individual room control with communication and presence control

The same amount of functionality levels is not, however, identified for every sub-service. For the mechanical ventilation domain, for instance, only two functionality levels have been recognised for the service "air temperature control", and its sub-service "heat recovery control: prevention of overheating":

Level 0: Without overheating control
Level 1: With overheating control

The exhibit of the functionality levels for the service can be seen in Table below. (Verbeke *et al.*, 2017)

Table 2. The functionality levels of the sub-service of air temperature control under the domain of heating (Verbeke et al., 2017)

Domain	Sub-Service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4
Air temperature control	Heat recovery control: prevention of overheating	Without overheating control	With overheating control			

According to the study team (Verbeke *et al.*, 2017) it is not enough to only identify the services, which cover the capabilities of making a building smart ready, but also to assess the criteria of the impacts that are relevant on the context of answering the user needs and the energy aspect that was emphasised by the EC (amending EPBD, 2016). The SRI-study team (Verbeke *et al.*, 2017) has suggested the following eight impact criteria, which should be covered when assessing the smart ready services in a smart building. The impacts to be considered are

- energy savings on site
- flexibility for the energy grid and storage
- self-generation of energy
- comfort
- convenience
- health
- maintenance and fault prediction
- information provided for the occupant.

The smartness of a building is characterised to refer to the capability of the building or its systems to sense, interpret, communicate and actively respond in an efficient manner to the changing conditions, and these aspects are emphasised when assessing the building's smart services according to the SRI-framework. (Verbeke *et al.*, 2017)

Smart readiness ranking systems

The ranking and scoring of the sub-services happen in terms of an ordinal ranking system, where the approach based on weighting the impacts is applied in this context. The methodology chosen must allow the impacts to be assessed and scored as well as to be adaptable to allow the policymaking process to develop the evaluation process further. According to Verbeke et al. (2017), fundamentally any weighting system can be applied to derive to the final SRI-score. Provisionally, the domains are assumed to be equally weighted, but a variant, where the impacts are weighted by the assumed importance, is also applicable. The functionality levels are assumed to have a relative effect on the identical sub-service functionality grades to be the same across the different impact criteria, domains and sub-services. In Table 3, a weighting system, where the impacts are equally weighted, is represented as an illustrative example of an equal weighting system. (Verbeke *et al.*, 2017)

Table 3. Domain-level impact weighting table, equal weighting (Verbeke et al., 2017)

Domain	**Energy savings on site**	**Flexibility for the grid and storage**	**Self-generation**	**Comfort**	**Convenience**	**Health**	**Maintenance & fault prediction**	**Information to occupants**
Heating	49,00 %	2,50 %	0,00 %	40,00 %	10,00 %	10,00 %	10,00 %	7,00 %
Domestic hot water	10,00 %	2,50 %	0,00 %	10,00 %	10,00 %	10,00 %	10,00 %	7,00 %
Cooling	6,00 %	2,50 %	0,00 %	15,00 %	10,00 %	10,00 %	10,00 %	7,00 %
Mechanical Ventilation	7,00 %	2,50 %	0,00 %	10,00 %	10,00 %	10,00 %	10,00 %	7,00 %
Lightning	10,00 %	2,50 %	0,00 %	10,00 %	10,00 %	10,00 %	10,00 %	7,00 %
Dynamic building envelope	7,00 %	0,00 %	0,00 %	5,00 %	10,00 %	10,00 %	10,00 %	7,00 %
Energy generation	0,00 %	2,50 %	80,00 %	0,00 %	10,00 %	10,00 %	10,00 %	7,00 %
Demand side management	0,00 %	40,00 %	10,00 %	5,00 %	10,00 %	10,00 %	10,00 %	7,00 %
Electric Vehicle charging	0,00 %	50,00 %	10,00 %	0,00 %	10,00 %	10,00 %	10,00 %	7,00 %
Monitoring and control	11,00 %	5,00 %	0,00 %	5,00 %	10,00 %	10,00 %	10,00 %	40,00 %

The final SRI-score is a result of a tailored assessment of the building. Depending on the building type, it might be that the services and their features under some domains such as heating, cooling, mechanical ventilation or dynamic building envelope are not necessarily present. Therefore, the SRI-scoring system considers the possibility of a building not to need the full range of the TBS identified in the methodology, and it does not make the building less smart in such cases. (Verbeke *et al.*, 2017)

Under the example of the equally weighting, the generic model to be used to calculate the weighted SRI-score is:

$$\boldsymbol{N = A \times a + B \times b + C \times c + D \times d + E \times e + F \times f + G \times g + H \times h} \qquad (1)$$

Where
N = the weighted SRI-score
A = the impact score (from 0 – 100) for Energy Savings
B = the impact score (from 0 – 100) for Flexibility for the grid and storage
C = the impact score (from 0 – 100) for Self-generation
D = the impact score (from 0 – 100) for Comfort
E = the impact score (from 0 – 100) for Convenience
F = the impact score (from 0 – 100) for Health
G = the impact score (from 0 – 100) for Maintenance and health prediction
H = the impact score (from 0 – 100) for Information to occupants

And
a = the impact weighting (from 0 – 100%) for Energy Savings
b = the impact weighting (from 0 – 100%) for Flexibility for the grid and storage
c = the impact weighting (from 0 – 100%) for Self-generation
d = the impact weighting (from 0 – 100%) for Comfort
e = the impact weighting (from 0 – 100%) for Convenience
f = the impact weighting (from 0 – 100%) for Health
g = the impact weighting (from 0 – 100%) for Maintenance and health prediction
(Verbeke *et al.*, 2017)

Verbeke et al. suggests the SRI-scoring to be presented via the heuristic scales. Here, the SRI-score is a result of a normalised score, where the score is derived by diving the sum of the nominal impact scores by the sum of the maximum possible impact scores and multiplying by 100 to get the percentage of the maximum score. An example of such a SRI-scale can be seen in Table 4. However, the methodology allows all sorts of scoring and ranking data to be applied, in addition to the principal score and heuristic ranking scale presented below. (Verbeke *et al.*, 2017)

Table 4. Example of SRI-scores and the heuristic scale (Verbeke et al., 2017)

SRI	Class
>86%	A
>72%	B
>58%	C
>44%	D
>30%	E
>16%	F
16% or less	G

2.2.2 Smart grid

A smart building can be seen as a smart environment, where the SRT efficiently communicate to each other as part of the TBS, and the system is controlled by a smart grid that leverages knowledge that resides in the outdoor environment (Building Efficiency Initiative, 2011). Therefore, in a smart building it can be argued that the biggest opportunity of digitalisation lies in the cloud services, which are operated in a building through a smart grid and prop (DR) (Wouters and Laustsen, 2017). The SRI-study team (Verbeke *et al.*, 2017) also considers the opportunity of a smart grid and DR, since one service of the TBS evaluated in the SRI-methodology is categorised under the main domain of the demand side management, which strongly focuses on the smart grid integration.

The concept of a smart grid has evolved several definitions, from which the key themes have been pointed out by the Canadian Electricity Association (2010). According to the research (Canadian Electricity Association, 2010), the connective themes in the definitions around smart grid are the communication, integration and automation that is sustainable, economic and secure. In align with these recognised key themes, the European Standardisation Organisations, CEN and CENELEC, have provided a definition for a smart grid, where the smart grid is defined as referred in the following:

A smart grid is an electricity network that can integrate in a cost-efficient manner the behaviour and actions of all users connected to it (generators and/or consumers) in order to ensure economically efficient, sustainable power system with high levels of quality and security of supply and safety. (CEN and CENELEC, 2018)

In addition, smart grids are the enablers of the companies and households to produce energy from renewable energy sources (RES), such as solar panels or wind turbines, and to sell it to other consumers through the existing networks (CEN and CENELEC, 2018). In other words, a smart grid is an electrical power grid, that is however more efficient and more resilient and thereafter, smarter than the conventional ones (Kolokotsa, 2016).

The opportunity of a smart grid in the building sector lies in making it possible to safely integrate more RES, smart buildings and distributed generators into the network of a smart environment (Kolokotsa, 2016). Smart grids deliver power more efficiently and reliably through the DR and provides a comprehensive control and monitoring capabilities, supporting also the transition of the built environment towards nZEBs by 2020 (EPBD, 2010). The opportunity to efficiently optimise the energy usage in buildings is provided by digitalisation through the cloud services, where the efficient operation of the services related in a building environment happens through the smart grid and the DR (Wouters and Laustsen, 2017).

Demand Response

One key characteristic of a smart building is the building's participation in demand response through the smart grid in order to contribute to the smooth and optimal operation of the energy assets (Verbeke *et al.*, 2017). Through the DR, it is possible to affect the building's energy usage and therefore, it provides a cost-effective alternative comparing to the adding generation capabilities to meet the energy peak and/or occasional demand spikes. By using the DR, the building occupants can modify their consumption in response to pricing signals, for instance. In a wider scale, the utilisation of the DR is expected to increase the energy market efficiency, as well to increase the security of the supply, leading to a more optimised electricity costs and reducing the environmental impact. (Kolokotsa, 2016)

Among the innovative technology entrepreneurs in the REC-sector, the PropTech-firms are actively striving for increasing their business value through demand response. Especially, the opportunity of utilising the weather forecast through smart grids and the DR is in the prime interest among these players in the field, where the heating, for example. In the case, the heating can be performed beforehand ahead of the actual need during a time period, when the demand peak is not yet reached. By integrating the PropTech-solutions, such as smart meters, smart sockets, domestic renewable energy generation and energy storage systems in a smart energy management environment, the system can support the demand side load management, distributed generation and distributed storage provisions through the smart grid. (Keles *et al.*, 2015) (Kayo *et al.*, 2014)

Demand response is an important part of the management of the distributed energy resources (DERs), where the initial idea is to implement the smart consumption infrastructure enabling DR, located at the interface between the distribution management and the TBS (El-hawary, 2014). Through the distributed systems, it is possible to support the effective exploitation of the energy storage from multiple energy sources. The benefit of such system is to improve the power quality and reliability of energy sources, where it provides the decentralisation of the supply, improved supply and demand matching, reduction of transmission losses and minimisation of downtimes, controlled by a smart grid. As a result, it can be seen that smart grids supports the socio-economic-environmental value of smart buildings. (Kolokotsa, 2016)

3 Investment characteristics in the real estate and construction sector

Real estate describes the built environment and it has a vital role in every aspect of the European economy, society and environment (INREV and EPRA, 2016). In Finland, the built environment comprises over 70% of the national GDP and the investments in the construction sector is equivalent to two thirds of the yearly fixed investments of the national economy (KTI Finland, 2014). Real property is one asset in the investment markets, in which the greatest effect on the economy comes from the construction activities of real estate development and maintenance, including refurbishment and repair of buildings (INREV, 2013). In addition, construction contracting, real estate investment, property transaction, leasing and real estate administration are part of the real estate business operations (Sanastokeskus TSK, 2012).

In real estate business, a REC-sector investor can invest in properties directly or indirectly. According to Sanastokeskus TSK (2012), a direct investment is a property investment in which the capital is invested in real estate, shares or a housing co-operative, whereas indirect property investment consists of investments in a real estate investment company or fund. The built spaces in the real estate business are commercial properties, used to produce immaterial or material commodities, and residential properties. Commercial market include offices, retail and service facilities, as well as production and logistic spaces. (Sanastokeskus TSK, 2012)

The main operators in the real estate and construction business are the space user, the space producers, including the investor, developer and constructor as the service provider and the government (Goddard and Marcum, 2012, p. 4). In this chapter, the investor logic is studied through the main investor types and their characteristics in the Finnish market. Additionally, the main investor strategies are identified as well as the drivers for the real estate investors in general in the field.

3.1 Property investor types and characteristics

Investments in the real estate business has traditionally been long-term investments and for decades, institutional investors, such as pension insurance companies and other pension schemes, have owned the leading market position in Finland. Additionally, a few non-listed companies as strong dwelling investors have had their share of the market. In recent years, the share of the direct property holdings have started to diverse, when smaller operators of non-listed funds and international investors have found the market and brought their business strategy into the Finnish market. (KTI Finland, 2014)

The latest report of the real estate market have been published in February 2018, which included a specification of the 30 biggest property investors of direct property holdings in Finland by the end of the year 2017 (KTI Finland, 2018b). In Figure 2 below, the list of the biggest property investors is exhibited.

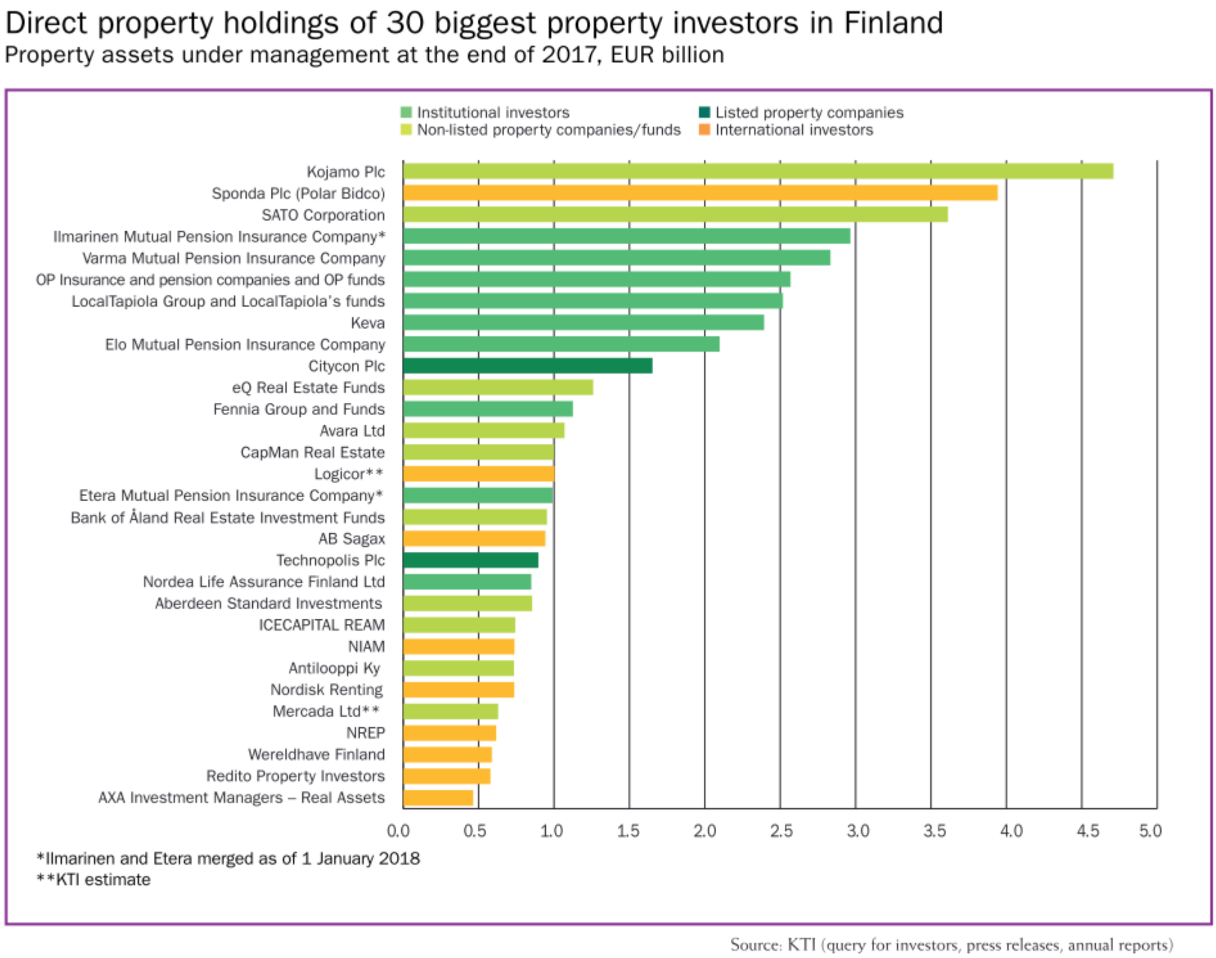


Figure 2. Direct property holdings of 30 biggest property investors in Finland (KTI Finland, 2018b)

Based on the figure, the investors are divided into four main groups; institutional investors, including various insurance companies and funds, non-listed property companies and funds, listed property companies and the international investors.

Institutional investors

Pension insurance companies and other pension schemes share the majority of the institutional investment ownership in Finland (KTI Finland, 2018b). The group of investors have targeted on long-term investments, where both residential and commercial investments are considered in their investment strategy (European Real Estate Forum, 2018). Through the long-term investments, the institutional investors have been able to benefit from higher yields due to the liquidity risk premium associated with the real estate investment. Here, in this thesis the yield level represents the predicted risk of the investment in a certain area. (INREV, 2013).

The group of institutional investors can be identified as a mixture of a basic public regime and employment-based pension insurance operators (KTI Finland, 2018b). In the Finnish public sector, there are two main contributors of pension funds, Keva and the State Pension Fund (Valtion Eläkerahasto / VER). However, the private pension sector owns the biggest share, where four major companies, Varma, Ilmarinen, Elo and Veritas have the major market share within this group of investors. (KTI Finland, 2018b) In general, these investors tend to do long term investments due to the nature of the pension business. Therefore, they favour investments with low risk, and take mostly care of the property in all phases of the building life cycle. Often, a pension investor might act as both the construction developer and owner of the property. Due to the nature of the investment, these investors are interested in possibly developing the property towards the direction where the maintenance costs of the property can be reduced through energy efficient solutions, for example. The institutional investors worldwide have a secure rental income, which is enabled by the long leases with financially sound tenants making a property particularly suitable for investing pension assets and other liabilities. (INREV, 2013)

Non-listed property companies

The group of non-listed property companies have increased strongly their market position in recent years in Finland, when Kojamo owned the largest share of the direct property holdings in 2017 and was the biggest private sector rental residential company according to Figure 2. The leading non-listed property companies in Finland have recently changed their business plan from only residential portfolios towards residential integrated market portfolios. Kojamo, for example, focuses today only on market-based dwellings under the housing brand Lumo, where the investor tends to do long-term investments with a focus on property development (KTI Finland, 2018b). Due to the divergent nature of the business compared to the institutional investors, non-listed property companies might be slightly more willing to take risks in their investments. However, the investors have the same aim of keeping the maintenance costs low, similarly to institutional investors. (KTI Finland, 2018b).

Real estate foundations

The group of fund management companies in the real estate field is consisted of operators from both institutional investors and non-listed property companies. In Finland, the market share has increased strongly in recent years. The largest share remains among the institutional fund management companies of OP, LocalTapiola and Fennia, where the fund managers are expanding to co-investments and investment management services through their group's property investments, but they do also offer investment opportunities to other clients. The investment focus is spread mostly to the field of commercial properties, where the rental revenues bring the largest share of the investment. (KTI Finland, 2018b)

In recent years, the variety of the Finnish real estate funds has increased. Funds are overall a strongly growing sector in the property investment business. In 2016, the non-listed funds accounted for a fifth of total investment property in Europe, where the market share of institutional investors of insurance companies and pension funds have been declining overtime. According to a study (INREV and EPRA, 2016), in general the shift towards a larger market share among funds can be seen to be driven by smaller investors new to the property business, who do not afford their own buildings. Non-listed funds are however constantly evaluating and improving their sustainability record. (INREV and EPRA, 2016)

The non-listed real estate vehicles are estimated to provide a wide range of opportunities. From funds to joint ventures, they can take several forms being flexible for a variety of business strategies, where the return comes from different sources. (INREV, 2018b) In Finland, EQ Real Estate Funds, for example, have raised its market share strongly and has today a noteworthy position as a direct property investor among other big property investor organisations. (eQ, 2017).

Listed property sector

After the delisting of Sponda in 2017, Citycon and Technopolis are today the largest operators among the listed property companies in Finland. Among the listed property sector investors, there is no coherent target group for investments, but the investment strategy is consistent. Citycon is specialised in commercial premises of shopping centre investments, development and management, whereas Technopolis owns, develops and manages the chain of business campuses in Finland, but also in other northern Europe countries, in the Baltics and in Russia. The investment strategy of owning, developing and managing the premises is logical, where the operators do long term investments and strive for improving the property value. (KTI Finland, 2018b)

International investors

Recently, an increasing number of international operators has entered the Finnish property markets. The foreign investors with international and diversified backgrounds operate in Finland with varying strategies and management practices. The market share of the investors have increased with a growth of 50% compared to the previous report in 2017 (KTI Finland, 2017, 2018b). After the delisting, Sponda became the largest international investor in Finland and at the same time the second largest property investor after Kojamo in the property investment market according to Figure 2. In general, the international investors have a great variety in their investment portfolios due to the reason that their property investment focus ranges from shopping centres to sale-and-leaseback investments. The foreign investors tend to favour ready-made packets, where the property development process is outsourced. However, Sponda is an exception, since it has a focus on developing shopping centres. It can be seen, that in general these investors aim for fast profit return and are not therefore interested in properties where a long-term investment is required. (KTI Finland, 2018b)

3.2 Investment logic in the real estate business

A competent investment in real estate requires a reasonable profit of the investment, where the required rate of the return must be in balance with the risk of the invested capital. Depending on the nature of the business, the investors tend to favour an investment philosophy, which meets the best the needs of the business strategy. Each investment philosophy, specific for an investor type, lies at a certain point on the risk-return spectrum. Commonly, the commercial property investment philosophies are categorised in three main segments, which are the core, value-add and opportunistic investment strategies. (INREV, 2013) These three segments, supported by the European trade body, INREV, has become the industry standard, although ‘core-plus strategy’ remains in use under the core investment strategy (Baum and Hartzell, 2012, p. 308).

To assist in ensuring that the property has the desired characteristics for allowing the investors to achieve the required rate of return, the investors apply analytical tools, which form the base for the investment logic. Real estate as a long-term business is in some extent influenced to the current market conditions, to which the investor can not affect. Therefore, real estate investors tend to rely on statistics available, and the variables there define the value of the property. (Goddard and Marcum, 2012, p. 49) After the return and risk analysis of the investment, the investors might have some extra drivers that direct their investment decisions. Depending on the investor type and investment strategy, the investor may seek for better image, reduced costs, recruiting benefits, healthier working environment or increased satisfaction amongst employees. Similarly, the investor might target on business advantage, moral responsibility, cost avoidance or opportunities to outperform. Depending on the investment strategy and investor drivers, the logic of the investment can be formed. (Pivo and Fisher, 2009)

3.2.1 Investment strategies

In general, an investment in built environment is considered as a good quality and income secure investment, and therefore it can be seen as an attractive alternative among other assets (INREV, 2013). The investment provides steady cash-flow, property appreciation and development potential, devolution benefit and inflation protection. Despite the relatively high advantage of the real estate investment, there are contrarily a few disadvantages, which increase the risk of the investment. Due to the big unit size of the asset, property is an illiquid investment increasing the risk in a case, where the market level drops suddenly. Real estate investment portfolio might also be hard to diversify, and therefore in most cases the investors have focused on a certain type of property assets within their business. In the real estate business, the management is often difficult, the integration of an allocation is slow, and the measuring and comparability of a property is hard. (KTI Finland, 2018a)

Before making an investment, the investor investigates the risk-return spectrum, that is outlined in their investment strategy. The nature of the investor portfolio affects to the risk level of the investment the investor is ready to take. Some investors are more willing to take risks than others, and therefore the investment strategies can be categorized based on the risk level of their assets. Next, the strategies of core and core plus, value-added and opportunistic investment are introduced.

Core and core-plus investments

Core investments are stabilised, low-leverage properties, mostly localised near or in metropolitan areas, where the properties are often highly occupied in areas with large population and high employment level (Baum and Hartzell, 2012, p. 308). The properties often feature credit quality tenants on long-term and triple net rent leases, in which the rental income is reliable and guaranteed (PeerRealty, 2016). Core assets are considered as the safest investment strategy among the other options, where relatively low risk level is a typical characteristic for the investments (Formigle, 2016). Contrarily to the minimal risk profile of the investment, the opportunity of adding value to the asset is low in core investments, limiting similarly the return of the investment. However, a core investment is defined as a safe asset, which is not easily influenced by the economic downturns, where core investors can be seen to be least likely to lose tenants in such market downturns. (Formigle, 2016)

Since core assets are typically best in class properties centred on metropolitan areas, the investments can be large and expensive. Therefore, the investors are often wealthy entities, such as institutional organisations, who do not usually need leverage for their investments (Baum and Hartzell, 2012, p. 308). The low risk-return spectrum characteristic of the core investment strategy fits well to investors, who are not looking for fast return and are willing to commit long-term investments, which have a secured return in the future (Formigle, 2016).

Core-plus investments are mainly alike core investments, since as core investments, core-plus assets are focused on metropolitan areas, where the rental income of the investment is secured. Additionally, core-plus investments character a relatively low-risk level of the asset, similar to core investment strategy. There are nevertheless a few features, which increase the risk of core-plus investment, which respectively provides slightly more upside compared to the core investments. (PeerRealty, 2016)

In core-plus investment, several tenants of the property might have expiring leases, where the investment generates less cash flow, but contrarily the investment might get potential for increased returns via rent increases. Core-plus investment is for investors, whose nature of the business requires a safe return, but who are ready to take a slight risk in their investment strategy. (PeerRealty, 2016) Core-plus investors are more willing to take financial risk in their strategy, where they tend to employ higher leverage ratios through investing to properties with higher vacancy rates, for example. However, the overall risk-return spectrum is low, but slightly higher than for core investors. Listed property investment companies, for instance, share the ideology behind value-plus strategy in some extent. (Baum and Hartzell, 2012, p. 308)

Value-added investments

Value-added investment strategy characters relatively higher risk-return spectrum of the investment, where the target is to get the return through adding value to the property. The properties are often assets that require renovation and/or have a high vacancy rate but have a hidden value in the property. The potential of the upside comes from "buy-fix-sell" -strategy, where the value is added to a ready concept of a property. (Baum and Hartzell, 2012, p. 308)

Value-added investments have potential for a high return, but at the same time, the investor must be ready for taking risk in the investment. The investor must be ready for a higher degree of leverage, which is mostly required for improving the property to the current market standard. The upside of the investment comes from decreasing the high vacancy rate by improving management with more professional leasing, reducing the operating expenses or renting the vacant units through more effective marketing. (Baum and Hartzell, 2012, p. 308) In value-added investment, the market value of the asset is increased by creating a revised market portfolio for the properties (PeerRealty, 2016).

Following the value-added strategy requires often a specific business plan of improving the vacancy rate of the property. Commonly, the properties are first bought with a discount. Then the spaces, strategy and/or marketing are revised, and after the development, new tenants are brought, or the property is sold with a current market price.

A well-executed asset might bring a relatively high return of the investment, where the investor can make a substantial profit (PeerRealty, 2016). However, the strategy involves more risk and effort than the core and core-plus strategies (Formigle, 2016).

The popularity of the value-adding investment strategy seems to be increased in recent years among the direct property holding companies. Investment in ready property concept, of which it is possible to take the profit fast, seems to be more attractive in terms of risk and return, followed by the opportunity of the investment. Traditionally, non-listed property companies and foundations have been interested in value-adding investment strategy but lately, the strategy has increased its reputation especially among the non-listed foundations (PeerRealty, 2016). In a recent study (INREV, 2018a), it was found that value-added strategy in Europe was preferred ahead of core investment strategy for the third year running among non-listed foundations.

Opportunistic investments

The third form of investment strategy leads to shorter holding periods, where the investment characters an extreme turnaround situation of changing or modifying the use of a property. Opportunistic investors are not interested in long holding period and instead, the holding period of the asset might be considerably short, less than two years, for example. (Goddard and Marcum, 2012, p. 52)

Opportunistic invested properties are typically either highly distressed, new development projects or properties in emerging markets, such as properties in foreclosure in which the return of the investment is unforeseen by other investors (Goddard and Marcum, 2012, p. 52). The major risk factors in the investment refers to the extreme vacancy, structural issues or financial distress of the asset, where exists little or no cash flow (Formigle, 2016). Mostly, the investments are highly leveraged, which increases the risk level. (PeerRealty, 2016)

The investment carries a high risk with high profit, and therefore the strategy requires great expertise (Formigle, 2016). Most of the return of the investment is generated in the future, as part of the future income or the sale or refinancing of the asset. The opportunistic investment strategy characters the highest risk among the three other categories, reflecting the highest returns and upside. The strategy is attractive for sophisticated and wealthier investors, such as some international investors, for example, which have found an unforeseen potential from the Finnish markets. (PeerRealty, 2016)

Summary of the investment strategies

The four main investment strategies, core and core plus, value-added and opportunity, differentiate in terms of their return-risk profile, but also the expected upside of the investment, which is strongly reliant on the risk of the investment. Additionally, the length of the holding periods ranges strongly, where in core strategy the investor might own the property for decades, whereas in opportunistic strategy the ownership might last less than two years. The property investment strategies in the risk-return spectrum are illustrated in Figure 3.

Figure 3. Property investment strategies in the risk-return spectrum (Formigle, 2016)

3.2.2 Investment drivers

Real estate investors follow the strategy chosen in their investment portfolio, which is in align with the values the investors have agreed with. The investment strategy forms the bigger framework, but does not state the exact drivers, which direct the investors' investment decisions as part of the investor strategy in the real estate business. According to Falkenbach et al. (2010), the different drivers can be divided in three different categories; external drivers, corporate level drivers and property level drivers. Legislation and national standards typically set the minimum requirements for directing the investment decisions. However, also prices and rent levels as well as financial incentives and taxes affect the profits of the investment, which also direct the investment depending on the strategy the investor follows. (Falkenbach *et al.*, 2010)

Property level drivers

According to the categorization of the drivers presented by Falkenbach et al. (2010), the risk level, property costs, property value and rental income form the logic for the real estate investor in the property level, where factors such as the yield level and vacancy rate affect the value of the property. The most important factor defining the value of the property is however the location. (INREV, 2013)

The yield level, known also as the capitalisation rate, is tied into the market rents in a certain district, where the yield is the sum of risk free rate and risk premium minus the presumed annual net rent growth percentage plus the percentage of replacement costs of the capital invested. (Sanastokeskus TSK, 2012) The return of the investment is strongly related to yield level, as well as the rental income, where the rental income is defined as the monthly gross rent. Monthly gross rent is also known as the potential gross income (PGI) of the property, from which the net operating income (NOI) is the property value after the maintenance costs are reduced from the PGI. Additionally, the deductions, known as the effective gross income (EGI), such as credit costs affect the monetary return of the property. (Allen, 1989, p. 46) According to Vimpari and Junnila (2017) the property value can be calculated with a simplified investment logic equation, where the property value is defined based on the rental income, operating expenses and required yield as presented in the following:

$$\frac{\textbf{\textit{Rental income}} - \textbf{\textit{Operating expenses}}}{\textbf{\textit{Required yield}}} = \textbf{\textit{Property value}} \tag{2}$$

Through the rental income, the property owner must cover all the long-term expenses of the real estate life cycle and therefore a high vacancy rate causes a high risk. A big vacancy rate is one of the greatest risks in real estate business, and at the worst, it lowers the investors interest in long-term investments. (KTI Finland, 2014) Through maintenance and operating costs, the investor can affect the profit of the property and thereafter it will also affect the value of the investment. The investor can not affect the market rent level, and therefore the location of the property has a significant impact on the value through different vacancy rates derivative to areas. However, the investor can affect the image of the value, which the users expect to get but the effect of the image benefit is hard to reason explicitly for the investor. Another possibility to influence positively the property value is through the maintenance costs produced by the property as well as the facility services. (Sanastokeskus TSK, 2012)

The operating expenses as part of the facility services can be considered to have a significant effect on the value and investment decision of the property. Operations expenses include all the costs related to the real estate maintenance, electricity, heating, water and waste management, which can be identified as the key cost drivers of real estate investment. (Goddard and Marcum, 2012, p. 192) Generally, all costs caused by the existence of real estate influence the value of real estate. Capital costs, taxes and operating expenses are all costs that are caused by the existence of real estate. The specification of how the costs are divided between the property owner and user is defined in the lease agreement. (Sanastokeskus TSK, 2012)

Corporate level drivers

As a result of the literature review made by Falkenbach et al. (2010) the authors were able to identify only one corporate level driver in terms of environmental sustainability, which was the image benefit. However, the image benefit is hard to validate, since the property value equation does not support explicitly the value of it., which was also found by Falkenbach et al. (2010), as the amount of the papers providing empirical evidence of the value remained limited. According to the literature review made by (2010), it was clarified that there are studies in the market indicating that green buildings, for instance, would increase the value of the building and the tenants would be more willing to pay higher rents. Similarly Falkenbach et al. (2010) questioned, whether the certifications, such as LEED and BREEAM, would actually increase the value of the property, nevertheless especially LEED have stabilised its position in the REC-sector market. On the other hand, some market players have chosen to make strategic decisions to invest or operate only in certified properties (APUDG, 2008), which would support the value of image benefit as an investment driver.

External drivers

The external drivers are the bellwethers in the REC-sector, where the national, European and worldwide legislations and standards sets the minimum requirements for the property business (Falkenbach *et al.*, 2010). Especially today the EBPD (2010; 2016) directs the building sector in the EU towards the 2020, 2030 and 2050 energy efficiency plans, which set up a driver for the investment decisions as well. Today, the environmental and energy certificates are a burning topic in the business, and thereafter those were identified as external investment drivers as well by Falkenbach et al. (2010).

4 Research methodology

The fourth chapter starts the description of the empiric research of the study. The objective of the empiric research is to answer the research questions, but also to validate the relevant points highlighted in the literature review. Before deciding the most suitable methods, their suitability in terms of multiple factors, such as efficiency, accuracy and reliability must be considered to achieve the desired outcome of the empiric research (Hirsjärvi and Hurme, 1982, p. 13).

The research methods are traditionally categorised into either quantitative or qualitative approaches, of which the qualitative research was evaluated as the most suitable approach to the study presented in this thesis. Qualitative research is feasible in cases, where the objective is to place the research and the findings in real-life context as comprehensively as possible. In general, a qualitative research aims to find and reveal facts instead of verifying the already proven statements. (Hirsjärvi *et al.*, 2007, p. 157) Some commonly known qualitative research methods are enquiries, interviews, case studies, observations and document research (Hirsjärvi *et al.*, 2007, pp. 186–187; Tuomi and Sarajärvi, 2009, p. 74), and the material gathered through such research process can be analysed by using a content analysis. The material gathered through a qualitative research tend to be scattered, and therefore content analysis aims to clarify and outline the material and assist the researcher in interpreting and concluding the data in a clear and coherent manner. In content analysis, the interpretation can be done in three additional ways, data or theory based or in a theoretical manner. (Tuomi and Sarajärvi, 2009, pp. 108–109)

According to Hirsijärvi and Hurme (1982, p. 8), a multidisciplinary and -methodological approach to the research provides a noteworthy benefit in terms of the variety and reliability of the research, especially in cases where the nature of the material is fragmented. Interviews, for example, are commonly utilised as a subsequent method to place the findings of the research in real-life context. A preliminary research before the interviews might be comprised of the literature review, but also a case study is seen as a suitable preliminary method, where a more in-depth data can be discovered. The findings from the preliminary research can be then validated and revealed through a suitable subsequent method, such as interviews (Hirsjärvi and Hurme, 1982, p. 8; Yin, 2014, p. 110)

In the context of this study, a case study was chosen as the preliminary research method and interviews as the subsequent one, where the research was based on the literature review presented in Chapters 2 and 3 in this thesis. In this research, the databased content analysis was applied to summarise the findings from the case study and semi-structured interviews into a written form. The analysis is traditionally performed in three steps, first the material is reduced, secondly the reduced material is grouped based on the arising themes, and finally the results are put into real-life context through the abstraction. In this chapter, the methodology behind the research methods of a case study and semi-structured interviews are presented.

4.1 A case study

The prime objective of a case study is to observe an individual case, occasion or a group of cases, where the contemporary phenomenon is investigated in depth in its real-world context. The method can be divided based on its characteristics into three categories, exploratory, descriptive and explanatory case study. An exploratory case study strives for identifying the research questions or procedures to be used in a subsequent study, where a descriptive case study pursues describing a phenomenon in its real-world context. The third category, an explanatory case study aims at providing an explanation how or why some condition came to be. (Yin, 2014, pp. 237–238)

The characteristics of a case study might possess features from the exploratory, descriptive or explanatory studies, but depending on the case, the features of the categories might also overlap each other (Yin, 2014, pp. 8–9). In the context of the case study performed in this thesis, the case study was seen to characterise features from all three case study categories, of which the exploratory case study remained as the dominant method.

4.2 Interviews

Interviews are commonly utilised to address ‘how’ and ‘why’ type of research questions (Yin, 2014, p. 110). The research method can be implemented as a structured, semi-structured or as an open interview, of which the semi-structured interview was selected as the approach due to the fragmented nature of the subject in this thesis. The material regarding the investment logic on smart buildings was considered as fragmented due to the reason that there exist no researches available on the issue. Therefore, semi-structured interview, known also as the focused interview, was chosen as the method for collecting information of the theme through a natural and casual atmosphere of a conversation. The chosen themes structure the interviews but leave room for some unpredicted matters that might arise along with the conversation, which would not have become clear with any other data collecting method (Hirsjärvi and Hurme, 1982, p. 8). During the interviews, the researcher is allowed to pose some additional and unprepared questions to clarify those unpredicted statements and arguments. (Tuomi and Sarajärvi, 2009, pp. 74–75).

5 Research process

In the fifth chapter of this thesis, the research methodology presented in Chapter 4 will be implemented as part of the empiric research process. In the context of the research, a multimethodological approach was put into practice, when an exploratory case study and semi-structured interviews were utilised in a qualitative research. Due to the nature of the research, the process was comprised of two research processes, of which the case study performed as the preliminary research and the interviews as the subsequent one. Here, these processes will be approached piece by piece to provide an explicit overview of the research.

5.1 Performing a streamlined smart readiness indicator assessment for a pilot case building

The case study was experimented as an individual research, which aimed to provide an explicit answer to the preliminary research question considering the smart readiness of the multi-purpose campus building. In addition, as part of the experiment the objective was to explore the streamlined version of the SRI-framework in a real-world context. The process of performing a smart readiness rating for a pilot case building started in March 2018 by getting to know the Interim report by Verbeke et al. (2017), where support for setting up such smart readiness indicator for buildings was provided. In June 2018, an updated version of the report was published (Verbeke *et al.*, 2018), but due to the schedule limitations of the research work, the interim report was decided to maintain as the source for the pilot assessment. In this chapter, the chosen pilot case building will be presented, as well as the process of performing the streamlined SRI-assessment. The assessment was performed during April and May 2018.

5.1.1 A multi-purpose campus building

At the time of the thesis research, the new main building in the Otaniemi campus area in Finland was under construction, which provided a great real-life example of a modern property suitable for performing the smart readiness assessment. The new main building was achieving for an ambitious goal of class A of Energy Performance Certificate (EPC), which indicated of some forward-looking building service solutions implemented in the building.

The new main building was designed to provide facilities for two types of commercial properties, office and business premises, which were integrated into one multi-purpose campus building. The building provides the facilities in educational matters for Aalto University School of Arts, Design and Architecture (ARTS) and School of Business (BIZ), an additionally does the building provide the business premises for the Otaniemi metro centre. (Nurmi, 2018). The new campus building is intended to be the living room of Otaniemi as well as the embodiment of Aalto University by connecting the three schools, the School of Engineering (ENG), BIZ and ARTS, in one campus area. (Aalto University Campus & Real Estate, 2016)

The architecture of the main building was a result of an open international design competition, Campus 2015, and Verstas Architects created the winning design. The winners had the best vision of the functionality of the building and provided a design, which answered to the changing needs of campus buildings, as well as was in align with the traditional architecture of Otaniemi campus area, designed by Alvar Aalto. (SAFA, 2013) The winning design of the campus building from outside and inside are visible in Figure 4 and Figure 5 below.

Figure 4. The winning design of the case building from outside (Verstas Architects, 2013)

Figure 5. The winning design of the case building from inside (Verstas Architects, 2013)

Characteristics of the case building

The building project of the new campus building started in 2015, and the construction is planned to be fully finished by the turn of the year 2019. An intermediate phase of the building project is already finished, and the premises for ARTS users and metro centre consumers will be opened in the forthcoming autumn in 2018. The educational premises for BIZ are planned to be finished by the turn of the year 2019. (Aalto University Campus & Real Estate, 2016) The building have been built in four floors, where the height and elevation treatments vary to adjust the modern structure to its surroundings in traditional Otaniemi campus area (SAFA, 2013). The building is comprised of different floor modules, where each module is designed to answer the specified user needs of the premises. The gross area of the entire building is 34000m2, of which approximately 20000m2 is allocated for educational premises in four floors, and around 6000m2 for metro centre in two floors. (Aalto Yliopisto, 2018)

The investor, owner and property developer of the building, Aalto University Campus & Real Estate (ACRE), had from the start a clear vision of an ecological and energy efficient building, which supports the goal of Energy Self-sufficient Otaniemi 2030 -project. In the new main building, the 2030 goal is supported through an extraordinary heating solution, for instance, where 67 heat pumps cover 90% of the building's heat demand, making it one of the biggest geoenergy plants in Finland. Similarly, to be in align with the concept of the self-sufficient Otaniemi, 95% of the energy demanded for cooling is produced with renewable geoenergy, and additionally 1400 solar panels as well as district heating are utilised as the indoor and spare energy sources. (Projektiuutiset, 2016) The energy efficiency in the building will be 83kWh/m2, class A (EPC), excluding the underground part, where the energy efficiency is 148kWh/m2, class B (EPC) (Aalto University, 2018). The characteristics of the campus multi-purpose building are summarized in Table below.

Table 5. Characteristics of the multi-purpose campus building (Janhunen, 2018)

Multi-purpose campus building			
Floor area [m2]		**Energy efficiency [kWh/m2]**	**EPC-class**
Educational premises	20000	83	A
Business premises	6000		
Underground		148	B

5.1.2 A streamlined smart readiness indicator assessment

In April 2018, the first meetings regarding the possibility of applying the campus property as the case building along with the thesis research were held with the ACRE Building Services Manager and Project Manager of Electricity of the property owner and investor. In the meetings, the building's suitability and relevance of becoming the pilot case for the SRI was evaluated, and especially its relevance regarding the smart readiness assessment was in the prime interest. The streamlined SRI-assessment was shortly described with the ACRE representatives and as an outcome of the meetings, the case building was agreed to be suitable for becoming the pilot case of the research. The process of setting up the SRI-rating for the campus building was conducted in May 2018.

The smartness evaluation of the multi-purpose campus building was accomplished according to the streamlined SRI-version (Verbeke *et al.*, 2017), visible in Appendix 1**.** The assessment comprehended five main steps, which lead to the eventual SRI-score of the building. The five steps experienced during the assessment were

- Step 1: Selection of the services relevant for the building
- Step 2: Assessment of the functionality level of each relevant service
- Step 3: Calculation of the impact scores and application of the weightings
- Step 4: Calculation of the maximum obtainable score for the building
- Step 5: Calculation of the SRI-score.

In the interim report (Verbeke *et al.*, 2017), an outsourced inspector was advised to be used as part of the assessment. However due to the nature of the research, an outsources inspector was not present in the assessment. The Manager of the Building services and the Project Manager of Electricity from ACRE accomplished the steps 1 and 2 of the assessment in cooperation with the thesis researcher. The thesis researcher performed the steps 3, 4 and 5 of the assessment.

Step 1: Selection of the services relevant for the building

The first step of the assessment required a triage process, where the services relevant for the multi-purpose campus building were chosen based on the technical documents and the knowledge of the ACRE representatives. In the case of the property, 10 domains with 45 sub-services were recognized and assessed out of the 53 possible sub-services, identified in the streamlined-SRI. The sub-services were omitted from the case study assessment in cases, where the service was defined as irrelevant in the case building according to the ACRE representatives, or the service was recognised as not present in the building type based on the SRI-framework.

In the main domain of the domestic heat water, the sub-services with codes DHW-1a, DHW-1b, DHW-1c and DHW-1d were excluded from the assessment due to the reason that they are not applicable in a district heating plant according to the ACRE representatives. Similarly, in the main domain of monitoring and control, the sub-services with codes MC-2, MC-8 and MC-9R since the services were not identified as present in the multi-purpose campus building based on the SRI-framework. The sub-services excluded from the assessment can be found from Appendix 2, marked with grey colour.

Step 2: Assessment of the functionality level of each relevant service

The second step of the assessment included an evaluation of the functionality level of each sub-service implemented in the building. The assessment was made in cooperation with the ACRE representatives, who did the evaluation based on their knowledge of the systems. In addition, a review of the technical documentation was partly applied when assessing the smartness of the services in cases, where the representatives had a lack of knowledge.

Step 3: Calculation of the impact scores and application of the weightings

The last three steps were done in an excel based tool, created by the researcher by following the instructions provided in the Interim report (Verbeke *et al.*, 2017). For each relevant service, the functionality level was filled into the tool from scale 0 to 4, where the best score (4) represented a progressive smartness of the service and the lowest score (0) a non-smart service. The scores for each relevant sub-service were filled into the tool by the researcher, based on the ACRE representatives' knowledge of the correct functionality level from step 2. The calculation tool aggregated the nominal scores and weighted them by domains according to the equal weighting table shown in Table 3 on page 13.

The equal weighing table applied as part of the pilot case was suggested to be applicable for office buildings in the SRI-methodology (Verbeke *et al.*, 2017). Due to the nature of the multi-purpose campus building, where the premises were designed to mainly support the educational purposes, applying Table 3 was considered as relevant. The outcome of the step 3 was a weighted nominal score of the smartness readiness of the sub-services identified in the case building.

Step 4: Calculation of the maximum obtainable score for the building

The calculation of the maximum obtainable score for the multi-purpose campus building is dependent on the maximum possible score of the services selected relevant after the triage process accomplished in step 1. The same scoring process was accomplished as presented in step 3 for the maximum smart readiness of the building. Similarly, the same impact-weighting table was applied as introduced in step 3 and a weighted maximum obtainable score was the outcome of step 4.

Step 5: Calculation of the SRI-score

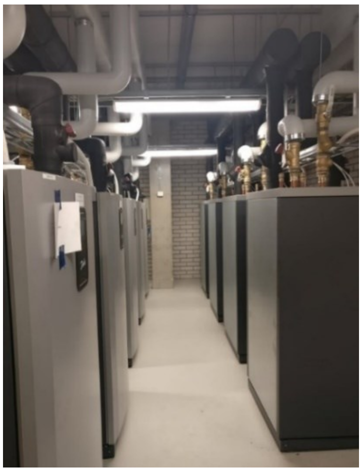
In step 5, the final score of the smart readiness assessment was calculated by the researcher. The SRI-score is a result of a normalised score, where the final score is derived by diving the sum of the weighted nominal impact scores by the sum of the weighted maximum impact scores and multiplying by 100 to get the percentage of the maximum score. The smartness of the building is evaluated based on a scale presented in Table 4 on page 14.

Time-cost evaluation

In addition to the already mentioned steps, which were accomplished as part of the SRI-assessment, according to the Interim report (Verbeke *et al.*, 2017) it is required to secure that the time versus costs of the assessment is applicable. In the context of this research, the time versus costs of the assessment included the working hours that were spent by the ACEE representatives and thesis researcher to conduct the assessment.

A walk-through inspection

A walk-through inspection is not necessary according to the Interim report (Verbeke *et al.*, 2017), but it can provide additional support for the assessment. The thesis researcher had the possibility to get a walk-through in the multi-purpose campus building and was able to assess the heating and cooling systems in the engine room, for example. The inspection was performed on the 15th of May 2018. The pictures below have been taken during the inspection. Picture 1 presents the heat pumps, Picture 2 the cooling system and Picture 3 shows the solar panels on the roof of the campus multi-purpose building.



Picture 1. The heat pump system in the case building (Janhunen, 2018)

Picture 2. The cooling system in the case building (Janhunen, 2018)

Picture 3. The solar panels on the roof of the case building (Janhunen, 2018)

5.2 Preparing and conducting semi-structured interviews with representatives from companies in the real estate and construction sector

The interviews were put into practice as a subsequent research method after the case study, where the smartness of the multi-purpose campus building was assessed and rated. The results found from the preliminary research method were partly applied in the interviews. The semi-structured interviews were held between May and August 2018 with the Finnish real estate and construction sector specialists. The interview questions were not showed to the interviewees beforehand. However, the structure of the interview was presented in the beginning of each interview. Each interview was recorded and transcribed afterwards. The permission to use the interview material in the context of the research was asked in the beginning of the interviews. The detailed information of the interviews, including the name of the company, the name and position of the interviewee, and the time and place of the interviews are presented in Appendix 3**.** The interviews were held in Finnish.

In this chapter, the reasoning of the interviewee selection is first presented and secondly the structure of the interviews is described. The main goal of the interviews was to identify the key drivers and strategies directing the investments on smart buildings, as well as to observe the value of a smart building from the real estate investment point of view.

5.2.1 The selection of the interviewees

Semi-structured interviews were held with Finnish REC-sector specialists. The interviewees were categorised into four specialist types; investors, TBS-specialists, consultants and property developers. The interviewees' specialist type, represented company as well as the position in the company are presented in Table below.

Table 6.The interview information of the REC-sector specialists (Janhunen, 2018)

Specialist type	Company	Position in the company
Investors	ACRE	Director; Real Estate Investment
TBS-specialists	SRV	Project Manager; Building Services
TBS-specialists	Aalto University	Professor of Practice in Smart Building Technologies and Services
Consultants	Granlund	Senior Consultant; Building Automation
Consultants	JLL	National Director, Head of Advisory
Property Developers	Bonava	Regional Manager
Property Developers	Skanska	Development Manager, Head of BIM team and Digital Services

The interviewees were chosen based on their knowledge around the real estate business and investments therein and especially their interpretation on the investment logic was on the primary interest. The length of the interviews varied in between 45 to 75 minutes.

Real estate investors

The prime objective of the research was to clarify the investment logic on smart buildings, and therefore a real estate investor aspect on the matter was observed in an interview with the Director of Real Estate Investments (Aalto University Campus & Real Estate, ACRE). Based on the interview with ACRE representative, the key idea was to formulate an idea of the investment logic they practice as part of their investment strategy, as well as reflect the logic on smart buildings. In addition, through the interview with the director, the target was as well to put into context and reflect the results of the pilot case assessment, since ACRE was the investor and owner, as well as the property developer of the multi-purpose campus building.

Technical building services -specialists

The technical building services aspect of the investment logic on smart buildings was observed with the Project Manager of TBS (SRV), who also was the main contractor in the multi-purpose campus building –project. Here, the target was to emphasise the value of the smart building services to the investment logic, as well as reflect the smart readiness of the building service solutions implemented in the case building with a TBS specialist.

Property developers

The property developers represent various roles in the REC-sector depending on the strategy they are committed to. Two property developers from the Finnish REC-sector were chosen, Bonava and Skanska. The Region Manager (Bonava) provided the perspective of a property developer who sells all the properties in which they are committed to, and mainly to the dwelling unit markets. The development Manager, Head of BIM and Digital Services (Skanska) in contrast, represented the perspective of both property developer and investor depending on projects. From the interviews with the property developer representatives, the goal was to get both the investor and service provider point of view of the investment logic on smart buildings. The role of a service provider was supposed to have more in depth understanding on the smart solutions than a regular investor. Therefore, the property developer with multiple roles in the field provided a great impression of a smart building as an investment in general in the sector.

Consultants

The fourth category of the interviewees represented consultants, who possess a wide and comprehensive understanding of the investment logic over the different investment strategies from the field. The consultants interviewed were the National Director and Head of Advisory (JLL) and the Professor of Practice in Smart Building Technologies and Services (Aalto University), who also performed as the Senior Consultant of Building Automation (Granlund). The goal with the consultants was to reflect the concept of a smart building on the investment logic as well as reason its possible value among the real estate investors. In addition, the consultants were intended to provide an impression of the conceptualisation of a smart building as well as the smart readiness rating system, SRI, which was one of the side objectives as part of the research.

5.2.2 The structure of the semi-structured interviews

In a semi-structured interview, the interview questions might vary depending on the background of the interviewees, and some variation in the format of the questions might occur due to the dialogic nature of the interview. The nature of each interview in this research was considered as individual, but the objective and chosen themes were similar for all the interviewees. The themes were chosen to structure the interviews, and they were formulated based on the literature review, but also some contextual aspects from the case study were utilised in identifying the most relevant themes to go through with the interviewees.

Even though the backgrounds of the interviewees varied, the researcher thought it relevant to go through the same themes and main questions with everyone. An additional theme was however covered with the representatives, who had a business connection with the multi-purpose campus building, applied as the pilot case building in this research. The interview themes were the following in an occasional order:

- 'Investment strategy',
- 'Definition of a smart building',
- 'Investment logic on smart buildings' and
- 'Smart readiness indicator'.

In addition, the theme of 'The characteristics of the multi-purpose campus building' was covered with the relevant representatives.

Each theme had one main question, which was presented for all the respondents. Under each theme, the conversation continued based on the respondents' answer. The researcher had formed some additional questions beforehand to support the conversation when necessary. After the first interview, the mutual order of the themes was slightly reorganised to guarantee a better flow in the interview, as well as to avoid leading the interviewee too much. The interview themes and the main questions are presented in Appendix 4 in both Finnish and English. The themes chosen to structure the interviews will be reasoned next. The mutual order of the themes varied slightly among the interviews.

Definition of a smart building

Through the interviewees' perception of a smart building, the researcher intended to point out the elements, which the respondents identified as the building concept characters. Through the case study, one type of definition was provided for the concept of a smart building, but here the researcher wanted to emphasise the REC-sector specialists' impression of the concept and avoid leading their mindset towards a certain direction. In addition, by pointing out the interviewees' own impression of a smart building, it was natural to continue later the conversation towards the investment logic on smart buildings from the interviewees' point of view.

The investment strategy

The investment strategy was seen a derivative of the investment logic the investor practices in the daily business. Therefore, it was important to clarify the investment logic the company performs, or their clients, to be able to reflect the investment strategy to the investment logic and create a linkage on smart buildings. Here the researcher wanted to point out the differences between the investment strategies and reflect them to the findings from the literature review.

Investment logic on smart buildings

The investment logic on smart buildings was prepared through the preliminary questions regarding smart buildings and the investment strategy, which clarified both the interviewee's perception of a smart building and the investment strategy in general. Through the theme, the goal was to identify the key drivers that create the property value of a smart building. The theme was built around the key drivers found in the literature review, which direct the investments in the REC-sector. The theme was considered as the most important aspect of the interview.

Smart readiness indicator

The theme of smart readiness indicator was designed to integrate the two research objectives present in this thesis. Here the methodology of the SRI-case study was presented for the interviewees and along with the conversation, the interviewees were able to assess their impression of such rating system. Through the conversation, the value of the SRI-rating system on the investment logic of smart buildings was as well estimated. The theme of smart readiness indicator was more in depth went through with the interviewees, who had a business linkage with the case building, concerning three out of six interviewees. In these interviews, in addition to the presentation of the methodology of the pilot case, also the results of the case assessment were reflected and validated.

The characteristics of the multi-purpose campus building

The fourth theme in the interviews affected only the owner and main contractor of the multi-purpose campus building. The theme around the characteristics of the case building intended to clarify the smart TBS decisions implemented in the building to provide more context for reasoning the pilot case study in the analysis phase.

6 Results

In the sixth chapter, the results found from the empiric research are presented. The results presented in this chapter are an outcome of the first two steps of the content analysis, in which the goal was to provide an answer to the research questions.

6.1 The smart readiness of the multi-purpose campus building

The case study intended to answer the preliminary research question “How smart ready is a campus multi-purpose building?”. The question was approached through a streamlined version of the smart readiness indicator assessment (Verbeke *et al.*, 2017). The smart readiness of the case building was evaluated based on the final SRI-score, which was an outcome of the domain-based normalised score, where the nominal and maximum obtainable impact scores of the identified domain-based services were analysed as part of the assessment. Here, the result of the SRI-assessment is first presented and then the outcome of the assessment is elaborated through the domain-based scores.

6.1.1 The final score

The final SRI-score is summarised in one table, which explicitly presents the scoring of the assessment and provides an answer to the preliminary research question. In Table 7, presented below, the numbers of the services included into the assessment are shown in the first cell from the left after the main domains. In the second cell in the table, the sum of the functionality level scores of the domain-based services included into the assessment are presented as well as their impact scores in the third cell. In the fourth cell from the left-hand side after the main domains, the sum of the maximum functionality level scores of the domain-based services are presented as well as their impact scores in the fifth cell. The last cell in the right-hand side in Table 7 below**,** presents the normalised SRI-score for each domain, where the nominal and maximum impact scores are resulted into the final SRI-score.

Table 7. The final scores of the SRI-assessment of the case building (Janhunen, 2018)

Domain	**No. of services**	**Nominal functionality level score**	**Nominal impact score**	**Maximum functionality level score**	**Maximum impact score**	**Normalised SRI-score**
Heating	12	19	24,42	30	38,55	63,3 %
Domestic hot water	1	0	0,00	1	0,60	0,0 %
Cooling	9	12	7,26	25	15,13	48,0 %
Mechanical Ventilation	8	14	7,91	19	10,74	73,7 %
Lightning	2	6	3,57	6	3,57	100,0 %
Dynamic building envelope	1	2	0,98	4	1,96	50,0 %
Energy generation	1	0	0,00	1	1,20	0,0 %
Demand side management	2	0	0,00	5	4,60	0,0 %
Electric Vehicle charging	2	3	2,91	5	4,85	60,0 %
Monitoring and control	7	10	8,80	18	15,84	55,6 %
Sum	45	66	55,85	114	97,02	**57,56 %**

The final SRI-score is bolded in the right bottom corner in the table above. The final score indicates, that the smart readiness of the multi-purpose campus building is 57,56% from the maximum obtainable score (100%) specific for the building type. The smart readiness of the building would then reach the class D, just below the class C based on the heuristic scale introduced by the study team (Verbeke *et al.*, 2017), where class A expresses a highly developed smart readiness in the building environment, as visible in Table 8 below.

Table 8. The SRI-scale applied in the rating (Verbeke et al., 2017)

SRI	Class
>86%	A
>72%	B
>58%	C
>44%	D
>30%	E
>16%	F
16% or less	G

In the case building, altogether 45 sub-services were included into the assessment and each of the services' smart readiness was evaluated. The sum of the nominal functionality level score was 66, whereas the maximum obtainable functionality level score was 114, as it was presented in Table 7. The impact scores were calculated based on the equal impact weighting table, which was presented earlier in this thesis in Table 3 on page 13. In the table, each of the eight impact categories had a specified weight factor for each main domain. The final SRI-score was a derivative of the operation, where the sum of the domain-based nominal and maximum impact scores were considered.

6.1.2 Domain-based scores

The final score provided only the end results of the SRI-assessment. It did not exhibit, why some of the domains reached 100% of the maximum obtainable scores, and why some of the domain-based services got zero points. Here the domain-based SRI-scores of the multi-purpose campus building are further elaborated. The ACRE representatives originally provided the reasoning of the chosen functionality levels as part of the SRI-assessment. The researcher has here combined the information gathered from the representatives and from the SRI-methodology to show the reasoning of the scoring. The detailed scoring of the sub-services is presented in Appendix 2.

Heating

The multi-purpose campus building reached about two thirds of the maximum obtainable scores under the main domain of heating, which indicated of rather smart heat control on both demand and supply side. Altogether twelve sub-services were included into the assessment, of which three services were considered as non-smart defaults. The sub-services of Heating-1f, Heating-2d and Heating-2e reached zero points in the assessment, because the required equipment for smart ready performance was missing in the services. The heat control in the case building was implemented as quite smart ready and automatically controlled, where the weather forecast was utilised to predict the heat demand, as well as to optimise the energy consumption. (Appendix 2)

Domestic hot water

The overall SRI-score of the main domain of the domestic hot water was zero points. In the SRI-methodology applied, the main domain included five sub-services, of which only one sub-service was implemented in the case building. The sub-service, control of DHW circulation pump (DHW-2), was implemented as a non-smart default, and therefore the overall score for the domain was zero. The other sub-services under the main domain, DHW1-a, DHW-1b, DHW-1c and DHW-1d, are not applicable in district heating plants, and therefore these services were omitted from the assessment. However, the maximum obtainable functionality level score of these services did not affect the final SRI-result, since these services were excluded from the assessment as part of the triage process presented in Chapter 5.1.2 on page 31. (Appendix 2)

Cooling

The main domain of cooling reached almost half of the obtainable points. All the sub-services presented in the framework (Verbeke *et al.*, 2017) were put into practice in the case building. In general, the cooling system was implemented with constant or no automatic control, which lead to slightly low scoring of the main domain as a whole. Four sub services, Cooling-1c, Cooling-1e, Cooling-1g and Cooling 2-a, out of nine were implemented as non-smart defaults. The cooling emission control (Cooling-1d) and interlock between heating and cooling and/or distribution (Cooling-1f) instead, were operated based on an external signal, which indicated of a developed smart control and therefore, these sub-services reached the maximum obtainable points according to the framework. (Appendix 2)

Mechanical Ventilation

Mechanical ventilation was one of those main domains, which reached a high SRI-score in the assessment. From eight sub-services under the main domain, all of them were implemented in a smart manner in the multi-purpose campus building. Half of the services reached the maximum obtainable scores, where an automatic coordination and occupancy detection of the room air temperature and flow control was implemented as well as the control of preventing the overheating in rooms. The maximum obtainable scores were reached by the MV-1a, MV-2a, MV-2b and MV-2c**.** Three out of eight sub-services reached two thirds of the maximum obtainable scores and one sub-service half of the maximum obtainable score. Overall, the services under the main domain of mechanical ventilation were according to the SRI-assessment implemented in a smart ready way. (Appendix 2)

Lightning

The main domain of lightning reached the maximum obtainable scores. From two sub-services, both were automatically controlled, where the control happened either based on occupancy detection system or daylight levels. The control was implemented individually in each room. Both Lightning-1a and Lightning-2 reached the functionality level 3 in the assessment. (Appendix 2)

Dynamic building envelope

The main domain of dynamic building envelope reached half of the obtainable scores, where only one sub-service was evaluated as part of the assessment. The window blind control (DE-1) was implemented with a motorised operation and automatic control in the case building, but the service was missing the predictive blind control, which would have indicated of some developed smart system. (Appendix 2)

Energy generation

The SRI-score for the main domain of energy generation was zero. The one sub-service evaluated under the main domain was implemented as non-smart default in the multi-purpose campus building. The local energy production and renewable energies (EG-5) existed in the building, but the coordination and optimisation of the production was not implemented in a smart manner. (Appendix 2)

Demand side management

The SRI-score for the main domain of demand side management was zero. Those two sub-services included into the assessment, smart grid integration (DSM-18) and DSM control of equipment (DSM-19), were implemented as non-smart defaults in the case building. There was no harmonisation between grid and building energy systems, and the DSM control of equipment was not present in the multi-purpose campus building. (Appendix 2)

Electric vehicle charging

The main domain of electric vehicle charging reached about two thirds of the maximum obtainable SRI-scores. The electric vehicle charging (EV-15) was implemented with medium charging capacity in the case building and the grid was balanced in 1-way with a controlled charging (EV-16). The maximum obtainable scores would have required a high charging capacity implemented as well as the 2-way charging, where the energy flow would have also happened from the electric vehicles to the grid. (Appendix 2)

Monitoring and control

The SRI-score for the main domain of monitoring and control reached about half of the maximum obtainable scores. From ten sub-services, altogether three were identified not to be included in the multi-purpose campus building, and they were excluded from the assessment. The functionality levels for MC-2 were not recognised in the SRI-framework (Verbeke *et al.*, 2017), and therefore the sub-service was automatically excluded from the assessment. MC-8 and MC-9R concerned only residential buildings, and therefore their maximum obtainable scores did not either affect the final SRI-score of the multi-purpose campus building.

Seven out of ten sub-services were evaluated as part of the assessment, where two of them were implemented in a smart manner. The heating and cooling set point management (MC-1) as well as the HVAC interaction control (MC-3) reached the maximum obtainable scores. The feedback information and reporting regarding current energy consumption (MC-5) and historical energy consumption (MC-6) provided trending functions and consumption determination, and they reached the functionality level 2 in the assessment, but they were missing the automatic readiness for analysing, performance evaluation and benchmarking. The fault detection (MC-4) and feedback reporting regarding predicted energy consumption (MC-7) were implemented as non-smart defaults in the multi-purpose campus building. The information regarding indoor air quality (IAQ) (MC-8) was gathered through air quality sensors and central monitoring, but the sub-service was missing the readiness for automatically analysing, evaluating and benchmarking the information, and therefore reached only half of the maximum obtainable scores. (Appendix 2)

6.2 The investment logic on smart buildings

The subsequent research question "How smart buildings affect the real estate investment logic?" was approached through the semi-structured specialist interviews. The goal of the interviews was to form an investment logic on smart buildings. From the interviews it was found that the added investment value of a smart building is defined based on the regular property value equation. In Chapter 3, a simplified version of the equation was introduced by Vimpari and Junnila (2017), who found the property value based on the rental income, operating expenses and required yield:

$$\frac{\textbf{\textit{Rental income}} - \textbf{\textit{Operating expenses}}}{\textbf{\textit{Required yield}}} = \textbf{\textit{Property value}} \tag{3}$$

Based on the equation, a regular property investment can be reasoned explicitly through these three variables mentioned in the equation above. From the research it was found that today the only way to validate an investment on a smart building is through the operating expenses. Through the increased rental income, there was not discovered any reliable evidence to increase the property value, neither through the required yield. In this chapter, the investment logic on smart buildings is presented based on the findings from the interviews through the property value equation variables.

6.2.1 Decreased operating expenses

All the REC-sector specialists agreed that the only trustworthy way to validate an investment on smart buildings would be through the decreased operating expenses. The expenses were identified as a straightforward approach to validate an investment, where the energy efficiency actions through a smarter operation of the heating system, for instance, would result into the increased property value. The interviewees described the increased property value to be easy to validate through the decreased operating expenses based on the equation:

$$\frac{\textbf{\textit{Rental income}} - \textbf{\textit{Decreased operating expenses}}}{\textbf{\textit{Required yield}}} = \textbf{\textit{Increased property value}} \tag{4}$$

The decrease of the operating expenses in a smart building can be explicitly reasoned by comparing the expenses to alike non-smart building. A reliable comparison was recognised by the specialists to be easy to perform due to the opportunity to explicitly calculate the profit on a yearly basis, and compare the results to previous years, for instance.

The operating expenses of a property were by the interviewees divided into two main categories, cost of operations and repairs and replacement costs. Thereafter, the added property value would be created either through a more efficient performance of the building, reflecting straight to the decreased operations costs of the property, or through a proactive and autonomous maintenance operation, reflecting to the decreased costs of the real estate repairs and replacements.

Costs of operations

The decreased costs of operations was seen mainly as a result of a more energy efficient building performance. The energy efficiency was considered to be linked to the optimised operation of TBS in a building environment, where the smart features, such as a smart grid and demand response, enable an increase in the energy efficiency. Being able to optimise the energy usage in a smart manner through the grid was recognised as valuable in terms of the changing outdoor environment conditions, for instance. Based on the forecast, the proactive actions in the building system could significantly decrease the energy required for the heating or cooling required, but also through the demand response it would be possible to be prepared for the heating and cooling peaks, when the electricity costs similarly rise.

The opportunity to decrease the costs of operations was assessed as a safe way to validate the investment in a smart building, which was estimated to be the reason by the interviewees, why the added value of a smart building was found to be strongly related to the costs of operations today. However, from the interviews it was discovered, that the expected decrease of the operating expenses does not provide enough evidence to actually start investing in smart buildings, even though the benefit can be calculated explicitly through the property value equation. The same issue concerned both the costs of operations and the repairs and replacements costs.

Repairs and replacement costs

The other mean of decreasing the operating expenses and increasing the property value of smart buildings was identified to be lying in the maintenance activities, which reflected straight to the repairs and replacement costs in a property. The repairs and replacements were seen to be linked with the developed smart sensor technology, where the TBS could interactively notify of the need of repairs in some part of the system, such as in the domain of the air ventilation. Among the interviewees', also an opportunity to increase a property value was recognised to lie in decreasing and optimising the number of the regular TBS control visits, and maintain the systems based on demand.

The repairs and replacement costs were considered already today as interesting from the investment point of view. Due to the accountable benefit of such smartness in a building environment, the driver was assessed among the interviewees to have a reasonable repayment period, which was recognised to increase the validity of the investment on smart buildings. Additionally, the interviewees found it possible to justify the savings compared to alike but a non-smart building.

6.2.2 Increased rental income

By contrast to the explicit value of the decreased operating expenses on a smart building's added investment value on a property level, it occurred much more difficult to find a way to explicitly reason an investment through an expected increased rental income. The validation appeared as indefinite, which made the reasoning difficult through the property value equation:

$$\frac{\boldsymbol{Increased\ rental\ income - Operating\ expenses}}{\boldsymbol{Required\ yield}} = \boldsymbol{Increased\ property\ value} \qquad (5)$$

The increased rental income as an investment driver is in general assessed as a valid way to justify the increased property value. However, the increased value as a consequence of the existence of smart features in a property, was by the REC-sector specialists recognised as impossible to reason explicitly through the regular property value equation. In today's property business, the concept of a smart building is not widely known among the possible tenants, nor the added value of such property as an investment is identified. Due to the currently missing market data of the added value of a smart building, the property value is impossible to reason through the increased rental income.

Among the specialists, there appeared some additional drivers to reason an investment on smart buildings through the increased rental income, which were assessed to have only an implicit effect on the property value and investment logic. A well-known brand, improved user performance and well-being were identified to have an implicit effect on the logic, as well as some certificates and standards as external drivers. Some of the interviewees, however, challenged the real value and effect of such implicitly reasonable drivers on the property value equation.

Brand

The value of brand was one of those drivers, which partly divided the REC-sector specialists. Especially from the dwelling unit market point of view it was highlighted that such driver as building brand does not affect the property value. By contrast in the commercial market, a building brand had evolved for sustainable building, for instance, and the added value of it was recognised in the business as increased rental incomes. In terms of smart buildings, however, no such brand value was found and therefore, it was not yet today considered to have an influence on the investment logic, but its significance in the future was emphasised.

Among the interviewees it turned out that the only way to bypass the regular investment logic and explicit reasoning of a real estate investment occurred to be through a strong brand, and it was assessed to have a positive impact on the rental income and vacancy rates in the commercial property markets. In terms of sustainable buildings, all the interviewees recognised the value of it in office spaces, for instance, but none was able to explicitly reason the added value of it through the property value equation. Among the specialists it appeared, that a commitment into a building brand, such as sustainability, might lead to the increased property values. In general, the value of the building brand was seen among the specialists as more important for foreign investors, since in abroad the value of a brand seemed to have a greater impact on the investment profit than nationally in Finland.

Well-being

The REC-sector specialists evaluated that one of the benefits of a smart building is the improved indoor conditions, which the specialists recognised as a topic in the construction business today. The reputation of the good indoor air quality and well-being in smart buildings could have a positive effect on the property value through the increased rental income. The other positive impacts of a good indoor quality were found to reflect the employee performance in offices, as well as health.

The increased rental income was here evaluated to be reasoned through the organisations' willingness to improve their personal brand among the employees, as well as the employers' readiness to pay more rent of the optimised indoor environment, where the employees are satisfied and perform better. The driver of well-being, as well as the brand, bring only implicit value on smart buildings, and cannot therefore be according to the interviewees considered as a valid driver based to the property value equation.

Certificates and standards

A well-known international certificate or standard was evaluated among the specialists to promote the familiarity of a building brand, when the certificate, for instance, and nature of the building represent consistent values. It was also noticed that a well-known certificate or standard might contribute positively, but implicitly, in the property values like a brand. Some examples of such certificate and standard arose from the interviews, where the Leadership in Energy and Environmental Design (LEED) was identified as a world-wide accepted metric for sustainable buildings and the Energy Performance Certificate (EPC) representing an internationally utilised certificate for energy efficiency. A similar effect is not according to the REC-sector specialists achieved through national standards, where the value does not exceed the country borders. It was estimated, that such metric for a smart building could evolve from the SRI or a similar framework, where the metric could act as an indicator of a smart building, and provide a definition for the concept.

A certificate or standard was recognised to have a similar brand value than a well-known building concept, which can contribute in increasing the rental income of a certain property, if it has been certified. However, the value was seen to be founded on the recognition among the stakeholders and therefore, such value for a smart building indicator does not exists today when the building concept in general is not admitted. From the interviews with the REC-sector specialists it appeared, that in the commercial market some potential for such indicator was recognised, where the indicator could be developed to support the employer branding. In the dwelling unit market, instead, the value of such indicator could increase the value of the building in the selling phase, where buildings could be marketed through a high smartness score.

6.2.3 Decreased required yield

Among to the REC-sector specialists interviewed it occurred that the third way to reason an investment on smart buildings could be implicitly through the decreased risk of the investment, referring to the required yield in the property value equation:

$$\frac{\boldsymbol{Rental\ income - Operating\ expenses}}{\boldsymbol{Decreased\ required\ yield}} = \boldsymbol{Increased\ property\ value} \quad (6)$$

In general, the required yield of the property is tied into the capitalisation rate of a certain area, known as the yield's level, but here the other means of decreasing the risk level of the investment were considered in terms of a smart building.

In a case where a smart building would have a brand value as a building concept, it could implicitly according to the research be estimated that the brand would have a positive effect on the rental income, either through the tenants' readiness to pay more rent, or through decreased vacancy rates. According to the interviewees, decreased vacancy rates could increase the cash flow in a case, where the tenant chooses between a smart and a non-smart building within the same price category. It can be thereafter assumed, that in a case where a smart building can provide an added value for a tenant with reasonable price, the tenant chooses the building with smart features, which was pointed out by one REC-sector specialist. However, reasoning this chain of events explicitly and based on the property value equation appeared as impossible in the case of a smart building today according to the specialists.

Another way to reason the added value of a smart building through the decreased risk would be the positive consequence of the improved monitoring and control practices in the property. The autonomous and interactive maintenance system could assist the building owner to prevent maintenance breaks, which would have a positive impact on vacancy rates as well as rental incomes. Additionally, the decreased risk for indoor quality problems, for instance, could decrease the overall risk of the investment according to the interviewees. The reasoning of such decrease in the risk level seemed to be explicitly difficult, or impossible to reason through the property value equation.

Overall, investing in the latest technology in a property business was considered as risky due to the long guarantee periods and unidentified share of responsibilities in smart buildings. In addition, the interviewees pointed out that predicting the development of these smart technologies is unsecured, since it might be hard to estimate the forthcoming development of the cable technology, for instance. All these matters were evaluated to increase the risk to invest in smart buildings, which does not support the added value of a smart building.

7 Discussion

In the seventh chapter of the study, the results found from the research are further elaborated and discussed, as well as their validity in real-life context is evaluated. Here, the third step of the content analysis is put into practice, and the goal is to conduct an objective analysis of the research results by utilising the already existing knowledge on the matters. The results found from the case study, as well as the smart readiness indicator in general, were elaborated with the chosen REC-sector specialists through the interviews. The investment logic identified on smart buildings from the interviews was by contrast reflected on relevant research papers available.

7.1 The smart readiness indicator as a smart building indicator

The evaluation of the SRI as a smart building indicator was conducted based on the smart readiness assessment of the multi-purpose campus building. The results were interpreted with the case building owner, main contractor and professor of practice of smart building technologies and services, who will be here identified as the case building representatives. The SRI-results of the case study were discussed based on the main domains and the coherence of the results was evaluated by reflecting on the knowledge of the case building representatives. Additionally, the suitability of such SRI-framework as a smart building indicator was assessed with the other REC-sector specialists as part of the investment logic interviews. The specialists' general opinion of such concept was considered based on a short presentation provided of the SRI-methodology.

7.1.1 Assessing the smart readiness indicator final score of the multi-purpose campus building in real-life context

According to the case building representatives, the multi-purpose campus building was from the start designed to express a modern illustration of future campus buildings. In the building, energy efficiency and smart operation of the technical building systems were the bearing themes, as well as the architectural vision designed for the building. The technical systems implemented in the building to maintain the heating, cooling and mechanical ventilation, for instance, were according to the representatives chosen based on their suitability in such operational environment specified for a campus building.

The multi-purpose campus building was reaching for class A of the Energy Performance Certificate. The technical building systems implemented in the case building were chosen to support the certification, and therefore the initial idea of the smart readiness of the building was presumed to be in align with the EPC. However, even though both the EPC and the SRI have an energy focus, the objectives of the certificate and the indicator vary. The main domain of the energy generation, for instance, reached zero points from the SRI-assessment, even though the renewable energy sources were one of the focus areas in the EPC.

To interpret efficiently the smart readiness of the multi-purpose campus building in real-life context, each main domain was further discussed with the case building representatives. The SRI-scoring was reflected on the reality in the building and thereafter, the validity of the SRI-result was possible to be evaluated.

Heating

According to the case building representatives, the SRI-framework did quite well take into account the all the means of smartness implemented in the building regarding heating, and they were in align with the results found from the assessment. The readiness for forecast services, for instance, was widely implemented in the case building, and its existence increased the SRI-score of the heating domain. Geothermal heat covered a major part of the heat demand in the case building, and district heating was implemented to support the main heating system in the case of faults. The coordination of these systems was automatic, which also increased the SRI-score of the domain.

In general, the case building representatives were well in align with the SRI-result of the heating domain, and the indicator took widely into account the variety of the smart technologies implemented in the building. However, by the case building representatives it was pointed out that some opportunities, which were implemented in the building to support the heating system in the future, were missing from the framework, such as the opportunity to use the superheat of the heat pumps. Today, the opportunities of superheat in terms of improving the energy efficiency is not recognised, but the chance to utilise it has been created into the pumps. These kinds of extra innovations implemented to support the heating systems, could be seen to increase the system's readiness for smart services, but today these innovations have not been pointed out, nor rewarded through extra SRI-points in the framework.

According to one case building representatives, these kinds of extra innovations should be included into the smart building assessment. Rewarding for valuable creations through such indicator could be identified to support the implementations in innovative technology solutions in the construction sector and could presumably increase the energy efficiency of the built environment in long-term. In addition, creating such opportunities already in the construction phase can be considered to decrease the need for expensive retrofitting in buildings in the future.

Domestic hot water

The SRI-score for the domestic hot water was zero in the multi-purpose campus building, which appeared as confusing for the building representatives. A closer interpretation of the main domain, however, provided an explanation for a such low scoring. Only one sub-service was included into the assessment, and the control of that specific service on the demand side was implemented as a non-smart service. The four other sub-services, which were excluded from the assessment, because the services were not applicable in buildings applying district heating. District heating was only applied in the multi-purpose campus building in cases, where the geothermal heat cannot meet the demand.

Apparently, the SRI-framework did not recognise the opportunity for the utilisation of geothermal heat through the heat pumps, and therefore the benefits of such heating system was not rewarded. The SRI-score of the main domain of domestic heat water can be seen as inaccurate. Increasing the amount of the assessed sub-services in the main domain, could have had a slight effect on the final SRI-score in the case, where the sub-services would have been evaluated as even slightly smart ready.

Cooling

The cooling system reached about half of the obtainable maximum scores in the SRI-scale, and the case building representatives were in align with the results. The sub-services regarding cooling were mainly controlled or operated on continuous programs, which decreased the smart readiness of the services. Only a few sub-services were operated automatically based on demand, such as individual room control with communication and occupancy detection, which resulted in higher SRI-scores. In general, the SRI seemed to point out rather well the SRT applicable for cooling services today, and the assessment was well in align with the reality according to the case building representatives.

However, some sub-services such as the storage operation of cooling, were seen by the representatives to have a lower relevance in Finland, where the yearly outdoor temperature requires more heating than cooling in general in the built environment. The implementations of energy-smart operation are, thereafter, focused on the main domain of heating, rather than cooling. It also explains why the heating domain reached better SRI-scores than the cooling. In general, to avoid implementing in irrelevant services only to reach more SRI-points, the SRI-framework could take into account the yearly operational outdoor temperature.

Mechanical Ventilation

The main domain of mechanical ventilation reached a rather high score in the SRI-assessment, and the case building representatives were well in align with the results. An efficient and optimised ventilation control was one of the focus areas in the multi-purpose campus building and the SRI-framework seemed to take into account all the up-to-date technologies implemented in the building. The sub-services were mainly controlled based on demand, where also automatic detection was implemented. It seems, that the SRI-framework was well in align with the Finnish construction practices, as well as with the quality standards regarding mechanical ventilation in general.

An efficient operation of mechanical ventilations can be seen as one of the main topics in the Finnish construction sector today, as it was pointed out by the case building representatives. A great number of educational premises have been retrofitted due to a bad indoor quality in recent years, which can be considered as one of the reasons why the up-to-date technology in the multi-purpose campus building have also been decided to focus on the services under mechanical ventilation. A well-operated mechanical ventilation was identified to have a straight effect on the indoor quality and health, which was found to increase the occupancy comfort in the building. The case building representatives were pleased, that the importance of mechanical ventilation was also notified in the SRI-framework.

Lightning

Lighting was the only domain reaching the maximum obtainable SRI-score in the assessment. The sub-services in the case building utilise a modern sensor-technology identifying the user presence in a room. According to the case building representatives, a smart lightning system has already become a norm in the construction sector. The technology for such smart operation has been part of the business already for a while and today in general all the new lighting systems support the modern technology, especially in the commercial properties.

Dynamic building envelope

The dynamic building envelope reached half of the maximum obtainable scores. The one sub-service identified, the window blind systems, was automatically controlled with a motorised operation. According to the case building representatives, the system was implemented in a rather simple way, and therefore the SRI-scoring was considered as reasonable as well as in align with the reality. Reaching the functionality level 4 in the assessment, would have required a predictive blind control, which can be seen to support the operation of heating and cooling. The opportunity in terms of energy efficiency of such system was recognised by the case building representatives, but it was not implemented in the building.

Energy generation

The SRI-score of the energy generation did not meet the expectations of the case building representatives. In the case building, energy efficiency was one of the bearing themes in the construction phase, and therefore investments especially in an efficient utilisation of RES had been in prime interest. A lot of effort and time was used to implement sustainable solutions in the building to support the energy efficiency, and the building was reaching for class A in EPC, indicating of some further developed smart solutions. However, in this case the EPC was not align with the SRI-result. From the SRI point of view, no extra points were given of energy efficiency without the smart readiness in them. Therefore, the SRI did not straight reflect the energy efficiency solutions implemented in buildings, which clarifies the discrepancy between the SRI-results and reality.

The SRI-framework can be considered as highly focused on energy-smart TBS solutions, and therefore such a low score on energy efficiency in general was a surprise for the case building representatives. It can be seen that the initial idea behind the framework is to encourage the implementations on energy efficiency even more, since in the future the different heating systems, for instance, must be operated in a consistent manner. Regarding the energy generation, it is not from the SRI-perspective enough to only have the solar panels, but the energy produced must be also operated and utilised efficiently. The standard for smart ready operation seems to rise all the time along with the development of the technology, which was pointed out by one representative.

Demand side management

A smart grid was not implemented in the case building and therefore, the main domain reached zero points in the SRI-assessment. The case building representatives were in align with the scoring. The implementation of smart grid can be evaluated to have a great effect on the energy efficiency in the forthcoming years. Today the technology might be seen as rather too complicated or modern to be efficiently implemented in the construction sector in Finland. However, a lot of potential was assessed to lie on the demand side management, and it was estimated among the representatives that in the forthcoming year its relevance will increase in the field, and more investments will be made to this domain.

Electric vehicle charging

In the case building, electric vehicle charging was implemented as a 1-way charging and with medium charging capacity. The case building representatives agreed with the scoring, which was in align with EV-technique available today. It was also pointed out, that the technology for 2-way charging (from electric vehicle to grid) already exists, and the opportunity has been provided in some other construction projects. In theory, the 2-way charging is already today possible to be realised in construction projects, but such opportunity is not possible with the technology implemented in the multi-purpose campus building, for instance. The 2-way charging is recognised as one of the future energy efficiency solutions, and therefore its existence in the SRI-framework as a developed smart service was considered as relevant to support the further development of electric vehicle charging in general.

Monitoring and control

The greatest opportunity in terms of a smart building and smart ready services was according to the case building representatives evaluated to lie in the main domain of monitoring and control. It was estimated that a lot of potential could be reached in the nearest future regarding the maintenance services, for instance. However, today the software to connect the already existing smart technologies is missing, and the services are not implemented as smart as they could be in the case building.

The scoring of the sub-services in the main domain of monitoring and control was considered as reasonable according to the representatives. The framework was seen to provide a sort of guideline to implement such smart services as part of the fault detection, for instance. The main domain provided a good overview of the opportunities regarding the smart operation from the monitoring and control aspect. Some opportunities, such as the monitoring of the soil, which were implemented in the case building but was not put into practice, did not increase the SRI-score, since the framework did not support such innovative implementations. Therefore, it could be reasonable to add a category in the framework, which evaluates the innovative implementations within each main domain category.

The final score

The final SRI-score was a weighted sum of the domain-based scoring, where the nominal functionality level as well as the maximum obtainable level of smart readiness for the specific building were considered. The final result of the assessment indicated, that the multi-purpose campus building reached the scoring just below class C based on the heuristic SRI-scale introduced in the SRI-methodology (Verbeke *et al.*, 2017). Reaching the class C in a scale, where class A indicates of some forward-looking building service solutions implemented in the building, would have required only a minor change in the current TBS-system in the case building. Updating the SRI-scoring of any sub-service in the framework with at least one functional level, would have been enough to reach >58% of smart readiness in the building and class C in the heuristic scale. Reaching the class B, which requires >72% of the maximum smart readiness based on the SRI-scale, would have required to update all the non-smart sub-services to reach at least the functionality level 1, but additionally implementing demand side management and electric vehicle charging, for instance, as a fully developed smart services including all the sub-services under the main domains. Therefore, based on the SRI-scoring, it can be argued that the class C in the heuristic scale could have provided a quite good indication of the case building's smart readiness, even though the official result of the SRI-assessment for the multi-purpose campus building was class D.

As mentioned, the final SRI-score was also the outcome of a weighting system, where based on eight impact categories and their weight factors, the domain-based SRI-scores were weighted. However, the case building representatives thought, that the weight factors of the eight impact categories were confusing, since a clear reasoning for the different factors was missing from the SRI-methodology. According to the SRI-study team (Verbeke *et al.*, 2017), the weighting table was as its current form still in the phase of development, but including the impact categories were considered as highly important to take into account the different meanings of smartness in a building environment. The statement was agreed by the case building representatives.

7.1.2 Defining the definition of a smart building

A smart building today, seems to be a well-recognised term, which is however missing a widely accepted definition. Therefore, as part of the research, the researcher wanted to ask the REC-sector specialists', interviewed as part of the research, personal impression of the concept of a smart building. It turned out, that regardless of the specialists' role, the interviewees had an alignment in their answers regarding the topic. According to the interviewees, a smart building was defined as an interactive service, which communicates with its users and occupants. Sustainability and energy efficiency issues were among the interviewees connected strongly to the theme, but also healthy indoor air as well as comfort were mentioned as the features of smart buildings. The most important characteristic of a smart building was recognised to be its adaptability to the user needs; the building should be able to independently provide an optimised indoor environment for its users and be able to learn based on the user specific data.

The features, which the interviewees named as the characteristics of smart buildings, were well in align with the eight impact categories, which the SRI-study team had listed in the SRI-methodology. The categories found by the team were, the energy savings on site, flexibility of the grid and storage, self-generation, comfort, convenience, health, maintenance and fault prediction, and information to occupants. The features of a smart building were mainly convergent between the definition provided by the SRI-study team and the REC-sector specialists' personal opinions.

The SRI strived for providing a definition for a smart building from the technical building systems point of view, where the energy-smartness seemed to be a bearing theme. According to the REC-sector specialists, the SRI-framework was seen to provide an easy way to get an overview of the nature of the building, but it nevertheless did not take inclusively all the meaning of smartness into account. The specialists thought, that the framework was focusing on the building's readiness for energy-smart solutions, and its effect on the features identified as part of the characteristics of smart buildings. Overall, the interviewees' thought that the SRI-framework provided a tool for comparing the smart readiness of equal buildings. Through such tool, it could be easy to show the beauty of those technical solutions, which would not become clear for a building user by any other way.

7.2 Evaluating the added investment value of a smart building through the identified investment logic

From the interviews held with the Finnish REC-sector specialists, it was discovered that the investment logic on smart buildings follows strictly the universally accepted property value equation. In the equation, the value of an investment is defined based on the property level drivers of rental income, operating expenses and required yield. From the research it was perceived, that today a smart building has only a vague value as a property investment. Based on the universal investment value equation, the value of a smart building was found to be possible to reason only through the decreased operating expenses in a property level. A smart building was seen by the interviewees to only implicitly increase the rental income or decrease the risk of an investment and therefore, through those variables it is not today possible to reason the added investment value of a smart building compared to a regular building.

In this chapter, the investment logic is further elaborated through the identified key investment drivers as well as the investment strategies, which add implicit value to a smart building. The drivers' and strategies' influence on the value of a smart building is evaluated through a discussion based on the research made in this thesis, where also some relevant research papers from the field are utilised.

7.2.1 The key investment drivers adding value to a smart building

According to the Finnish REC-sector specialists, the only way to explicitly reason a property value is through the universally accepted property value equation. The equation was presented earlier in this thesis in Chapter 6.2 on page 43. However, as it was found from the research, an investment on a smart building is not possible to be reasoned conclusively enough based on the identified property level drivers, and therefore the investment value of a smart building has remained as unrecognised.

According to the recent study conducted by Säynäjoki et al. (2017), the real opportunity of smart buildings is behind the huge amount of shared data that is available for organisations. From the thesis research it was found, that today it is not possible to provide enough evidence of the added investment value of a smart build through the regular property value equation. Therefore it can be argued, that the added value of a smart building is not found on the property level, but instead on the corporate and external levels. Based on the research made by Säynäjoki et al. (2017), the real value of smart buildings exists in the forms of smart communities and smart cities, which can be recognised as drivers adding value to smart buildings through the corporate and external level drivers. A model representing the different levels of investment drivers has been presented by Falkenbach et al. (2010), who introduced the framework to categorise the drivers directing investments on sustainable buildings. The categorisation of the drivers was previously introduced in this thesis in Chapter 3.2.2 on page 24. Here the categorisation provided by Falkenbach et al. (2010) is applied to reveal the added value of a smart building through the identified key investment drivers. The framework is visible in Figure 6 below.

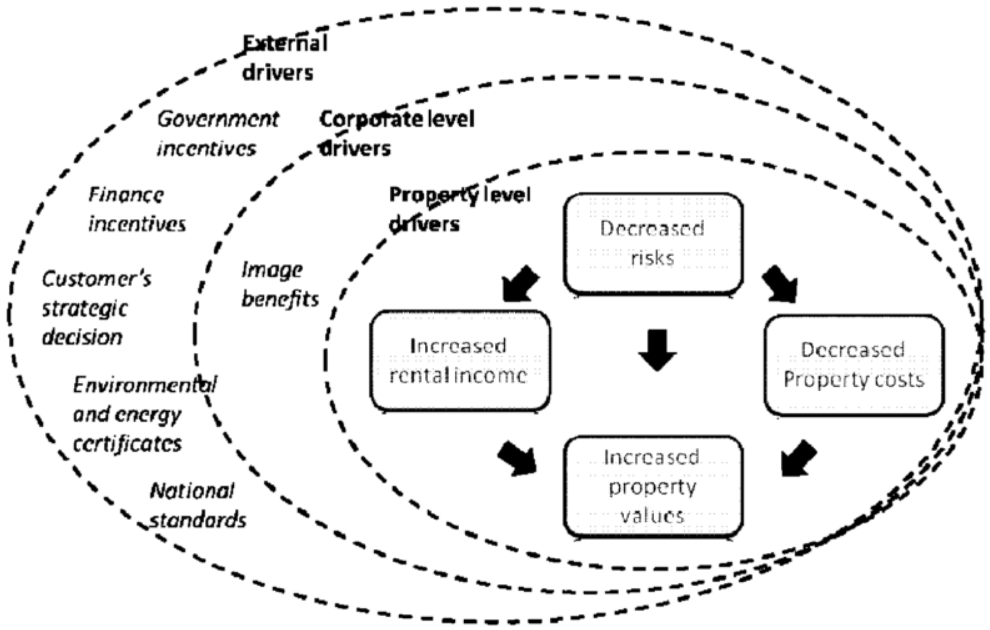


Figure 6. The framework of the investment drivers on environmental sustainability (Falkenbach et al., 2010)

Property level drivers

The property level drivers were identified among the REC-sector specialists as the ones directing the investments on smart buildings today, but which do not show the real value of smart buildings. From the research it was found, that the only valid way to reason an investment is through the decrease operational expenses. Digitalisation and especially digitising the commonly known practices were also recognised to provide some upside in the property maintenance business, compared to a regular building. However, even though the drivers decreasing the operating expenses were assessed to have an explicit effect on increasing the property value based on the property value equation, it did not according to the research provide enough evidence for the investor to actually invest in smart buildings. The benefit is in general dependent on the leasing agreement, and therefore an explicit reasoning of the increased property value is hard to define. A similar result was found from the research made by Falkenbach et al. (2010), where it was pointed out that even though it can be proven that the property costs in a sustainable building are decreased, it does not necessarily have a straight impact as an added property value due to the various nature of the leasing agreements.

In the interviews held with the REC-sector specialists, the interviewees agreed that the validation of an investment in smart buildings is difficult through the regular investment logic, where the positive effect on the rental income or required yield is not possible to reason explicitly. To justify the added investment value, the validation should happen through some additional way. In theory, the smart building features can be seen to decrease the risk level of the investment, as well as to increase the rental income, but the REC-sector specialists did not support the ideology. Similarly, Falkenbach et al. (2010) found, that the literature was missing the empirical evidence, which would support the positive effect of the decreased risk and increased rental income on the property values in terms of sustainable buildings. It was, however, clarified that the investors still tend to believe in the increased cash flow.

Corporate level drivers

From the interviews with the REC-sector specialists it appeared that the only way to bypass the regular investment logic was through a well-known brand. A similar result was resulted by Falkenbach et al. (2010) who had found, that the image benefits of sustainability made the investors to believe in increased cash flow and increased rental income on the property level, even though an explicit reasoning of the added investment value seemed to be missing. The key issue seemed to be the belief in the image benefits of the sustainable-labelled buildings in a corporate level. In terms of sustainability, the image benefits was identifed as the only corporate level driver adding investment value on sustainable buildings.

The image benefits of sustainability can be seen to be based on the belief of the business advantage gained through the driver. Today, a smart building has not yet reached a similar popularity as an investment asset and therefore, the image benefits of smart buildings cannot be utilised today. However, another way to reason an investment on smart buildings through the corporate level would be the well-being theme, recognised by the REC-sector specialists in the interviews. In commercial properties, the well-being could improve the image of a smart building and through the corporate level driver it could be possible to start increasing the property value. The regular property value equation was found not to support such futuristic approach, where the value of a smart building investment does not exist today on the property level.

In the dwelling unit markets, the increased brand value through the well-being theme of a smart building was not recognised to have any influence on the tenants' willingness to choose a smart building over a regular one. According to a recent study (Bonava, 2018), the regular citizens were found to value the most the low costs of living, but do not find a value in a smart building. The tenants appeared to value smart building features, such as good indoor air quality, but did not value a smart building itself. The survey results indicated, that the dwelling unit tenants today do not spot the benefits of a smart building and therefore, they do not value the smart building services, for instance, even though they value the features of the services.

As it was found from the Bonava survey (2018) in terms of the regular tenants, it can be argued based on the thesis research, that neither do the stakeholders in the corporate level today identify the real value of smart buildings. The features of smart buildings are well-known, as it was discovered form the interviews, but the positive effect of those smart features in a wider scale is nevertheless unrecognised. As it was found from the research made by Säynäjoki et al. (2017), the smart community is the key driver to extract value from smart buildings. Based on the property value equation, it seems evident that an investment on one smart building does not increase the property value enough compared to a non-smart building. However, due to the digitalisation, the benefit gained from the smart features will be repeated in the property level, when there is more than one smart building in the platform community. Based on the research (Säynäjoki *et al.*, 2017), smart buildings provide in the corporate level new ways for cash flow through the smart community, that is created on top of a platform. As result of a smart platform, the value of the operating expenses in the property level can be considered to be increased, and then it is possible to get deductions of the centralised electricity supply contracts, for instance. According to the research, it seems that the investment value of a smart building is actually achieved in the corporate level, through which it is also possible to affect positively on the property level.

External level drivers

The external level drivers have been identified as drivers, which direct the market from above. In the case of a smart building, EU level directives, for instance, were according to the REC-sector specialists notified to influence the investment logic already today. Through the amended EPBD (2016), for instance, the EU strives to support the built environment to move towards a smart ready built environment. Nevertheless, there does not yet exists a directive, which would require the buildings to achieve a smart readiness certificate, for instance, and therefore the driver is not applicable in today's real estate business.

Among the interviewees the sustainability certificates, such as U.S based LEED and U.K based BREEAM, were assessed to have an effect on the property value, even though none of the specialists was able to recognise the explicit value of the certifications. A similar result was found by Falkenbach et al. (2010). Based on the research (Falkenbach *et al.*, 2010), LEED-certified buildings were believed to provide better terms for financing or insurance, for instance, but a very limited empirical evidence was found to support the claim. In terms of smart buildings, the interviewees predicted that external drivers, such as customer's strategic decisions to invest or use only smart buildings, might become reality in the future. However, the real value of smart buildings in the external level, could be seen to lie in the concept of smart cities, which was introduced by Säynäjoki et al. (2017).

7.2.2 The investment strategies adding value to a smart building

The principles behind the regular investment strategies in the real estate business were covered in Chapter 3.2.1 starting from page 21, where the core and core plus, value-added and opportunistic strategies were found to affect the investment logic in the real estate business. The investment categories were based on the risk-return spectrum, where the core strategy represented a low risk and long-term investment, and opportunistic strategy represented the opposite, high risk and short holding periods. From the literature review different investor types were found to value some drivers more than the others and therefore, to create an image of how smart buildings affect the investment logic in the real estate sector, the identified drivers adding value on smart buildings were reflected on the regular investment strategies in the field.

Core and core plus investment strategies

In the construction business, where the lifetime of a property is typically several decades, those investors who tend to invest in long-term investments with low risk, such as institutional investors were, according to the a REC-sector consultant interviewed, evaluated to be the first ones to adapt smart buildings into their investment portfolio. The key investment drivers these investors most probably apply when making an investment decision are the property level drivers.

According to the research results, it could be identified as beneficial for these investors to invest in smart technologies in terms of decreasing the operating expenses in long-term in the property level. The right timing could be, however, seen as a topical issue for these investors, who want to invest in smart buildings. The investments on the up-to-date technology in a smart building requires a bigger initial investment and reasoning the investment might be hard especially in the beginning, when the added value of smart buildings has not yet been achieved and when the risk level of the investment is still high. A scenario for a core or core plus investor could be a situation, where the value of smart buildings have been already evolved in the market but their properties do not support the concept. Therefore, the right timing seems based on the research to be evident for these long-term investors. However, because the core and core plus investors tend, according to the literature review, to focus their property investments strongly on metropolian areas, it can be estimated that the value of those properties could stay high even though the added value of smart buildings would start to evolve outside the city.

In terms of the platform business, which was found as the key driver adding value on smart buildings, the core and core plus investors might have a great benefit of it due to the nature of their investment portfolio. These investors already have the community in their protfolio, but the community is only lacking the smartness. For these investors, smart buildings can be identifed as a great opportunity from the investment point of view, where the investors could negotiate great deals in terms of the property costs, for instance, for the properties in their community. The key issue for these investors might be the fact, that the property value equation, which today directs the investments strictly in the real estate business, does not support the key value of smart buildings.

Value-add investment strategy

According to the research, a value-add investor strives to increase the property value through the shorter holding periods, than core and core-plus investors. Therefore, these investors are not that interested in increasing the property value only through the regular property value drivers. These investors could be considered to be keen on increasing the property value through the corporate level drivers, such as brand or promoting the property value through the well-being theme. The smart building brand could be supported by an external driver, such as a smart building certificate, which the value-add investor could include into their strategy. Based on the research, a smart building indicator could be seen as a way to increase the value of the property and the metric could efficiently be applied by a value-add investor.

From the case study presented earlier in this thesis, it was found that completing one type of a smart building indicator, the SRI-framework, is quite straightforward way to assess the building’s smartness. Through such indicator, it is easy to point out the domains, where the smart readiness is missing from the services and thereafte, a property value could be increased through making the spotted improvements and then reach a higher SRI-score. The invocation of such driver, however, requires that the indicator would have been accepted as the metric of smart buildings and moreover, a smart building would in general have reached a common repuation among the stakeholders. Otherwise a value-add investor cannot increase the property value through such driver.

One REC-sector specialist estimated in the interviews, that the first steps towards reaching the common knowledge of such brand as the smart building indicator represents, are taken by some big international corporations. These non-investor corporations start to first demand for such a smart building indicator and then the supply of these smart premises representing the same values as the indicator does, starts to evolve. The driving force in the case would not be the investor, but the customer's strategic decision. The customer's strategic decision was mentioned also as an external driver in terms of sustainable building presented in the framework in Figure 6 on page 55. After the supply of such building brand has started to evolve, the other users start to also demand for such features as the smart building represents, and then the value-add investors, such as some international funds, could be seen to start taking the advantage of the building brand and increase the property value through such a smart building indicator.

As a result, it can be found that the brand value of a smart building increases and the value of the property will be developed also through the property level drivers. According to the REC-sector consultant, a similar chain of events happened with the environmental sustainability and the certificates representing similar values and therefore, it can be presumed that it might happen also for the concept of a smart building and its indicator. The claim can be supported by the findings by Falkenbach et al. (2010). Through the supposed increased value of such a smart building indicator, the effect of the driver can be recognised to develop, and it might become a more valuable driver also for the core investors. The developed value of the indicator could be thereafter, considered to increase the smart building brand value in general, and the concept would increase its awareness among the other players in the REC-sector. According to the research results, a great benefit for the concept of a smart building would be if the value-add investors would include the smart indicator into their core values, which could lead into the increased value of both the concept and indicator.

The value-add investors can be according to the research be identified as the key actors in increasing the common knowledge of smart buildings. The platform business, which was found as the key investment driver of a smart building, requires a comprehensive community before the benefit of it can be shown. Therefore, increasing the community of smart buildings through a smart indicator by a value-add investor, for instance, can be seen as relevant when affecting the investment logic on smart buildings.

Opportunistic investment strategy

As introduced in Chapter 3.2.1, an opportunistic investor represents a strategy with a high risk and fast profit with short holding periods. The number of opportunistic investors is rather small in the real estate business, and therefore identifying the valuable investment drivers for them appeared as difficult. Based on the research, the opportunistic investors are not the first ones to invest in smart buildings nor increasing the brand value of it. However, it can be expected that when the market evolves and is ready for the concept to develop strongly, opportunistic investors might be willing to invest in smart buildings and benefit from their increased value fast and with high risk. According to the interviews, property level drivers will not most probably direct the opportunistic investment logic, since the value of the property is not increased fast enough through the single property level drivers.

According to one property developer interviewed as part of the research, the greatest value of a smart building could arise among those investors who tend to invest in properties, which are located slightly outside the main city area. In these areas, the value of the property could be increased much faster than in the metropolitan area, where the tenants are ready to rent the properties without any smart technology only because of the great location. Investing in properties slightly outside the city area with good connection to the cities and increasing the property value through the implementations of smart technologies, could increase the selling price of the property, and would fit into the opportunistic investment strategy. However, today it is hard to estimate how the value of such property could be increased, since the regular real estate investment logic does not support such approach to increasing the property value.

According to the literature review, opportunistic investors invest based on the current market situation and they require fast return to their investment. Therefore, smart buildings can be seen to have a trivial significance today for those investors who follow the opportunistic investment strategy. The opportunistic investor will not supposedly be the first one to invest in smart buildings, but after the market has develop and the supply meets the demand in certain areas, they will most probably try to make the best advantage of a smart building.

8 Conclusion

In the forthcoming years, it appears evident that the nature of buildings will change and buildings are becoming more like services than solid products. Because of digitalisation, the passive nature of building is being revised and a more functional performance is adapted as part of the concept. In the REC-sector, smart buildings have been identified as a conceptualised version of the connected building and similarly as one example of the embodiment of digitalisation in the REC-sector. The research was focused around the theme of smart buildings and the definition as well as the investment logic on smart buildings were the objectives of this thesis.

The definition of a smart building was studied through an indicator introduced by the European Commission and a case study was set up to observe, whether such indicator could provide a universal definition for a smart building. From the research it was found, that the introduced smart building indicator, SRI, could be rather referred as an energy-smartness indicator, which would be applicable to evaluate the smartness of the TBS in a building environment. The indicator was not recognised to support the full meaning of a smart building, where also the smart community and smart platform were found as the key themes of digitalisation in the REC-sector.

In addition, the investment logic on smart buildings was studied in this thesis, where the added investment value of a smart building was clarified through the interviews held with Finnish REC-sector specialists. From the interviews it was found that today the investment logic follows the regular property value equation, where the increased rental income, decreased operating expenses and required yield are considered to add value to a smart building. The reasoning of an investment on smart buildings was, however, found to be impossible based on the regular property value equation. The key value of smart buildings was found from the corporate level driver of smart community, and its synergetic benefits affecting also the property level drivers. However, the added investment value of a smart building was not explicitly possible to be reasoned based on the regular property value equation, which directs the investment logic in the REC-sector.

9 Further Research

Based on the research it was found, that the smart readiness indicator introduced by the European Commission did not fully support the all means of smartness in the REC-sector. However, a universal definition of a smart building was found to be essential in increasing the property value of smart buildings. From the research it was also discovered, that the synergetic benefits of a smart building community gained through the corporate level, was identified as the key investment value of a smart building. Due to the reason that the investment logic applied in the REC-sector was found to be strictly based on the property value equation, which only measures the added value on a single property, the investment value of smart buildings is not possible to be revealed through the investment logic applied in the real estate business today. Based on the research and findings, the further research suggestions are concerning the universally accepted definition of a smart building, as well as the revision of the regular property value equation.

A suggestion of a universally accepted definition of a smart building

From the research it appeared, that a commonly recognised definition of a smart building is missing and it occurred as one of the main reasons why the brand value of a smart building cannot evolve today and bypass the regular investment logic. In general, the nature of a smart building appears as diverse and including the full meaning of smartness into one definition has occurred as difficult. The European Commission introduced one type of definition of a smart building through the smart readiness indicator framework, but the definition was not found to take the all means of smartness into consideration. It could be proposed, that more research could be focused around the complete meaning of a smart building, where maybe the term ‘smart building’ could be even revised to explain better the definition. From the researcher’s opinion a smart building indicator, which supports the full meaning of the concept, is evaluated as valuable when defining the term. The SRI-framework was from the researcher’s perspective found to fulfil its original function, which was to assists the European Union to reach its energy efficiency targets set for the built environment. Such indicator, however, was not seen as suitable for representing alone the concept of a smart building.

A suggestion of revising the regular property value equation

Today, the regular investment logic in the real estate market was found to strictly follow the regular property value equation, where the rental income, operating expenses and required yield define the property value. From the research it was discovered, that in terms of a smart building, there exists no added value based on the equation through any other way than the decreased operating expenses. As it was found, the property level driver does not alone add enough value on smart buildings to actually increase investments therein. It seems, that based on the regular investment logic, it is not possible to reason an investment on smart buildings, neither add the value of it. Therefore, some additional ways to define the property value, are proposed to be studied further.

The revised property value equation should take into account the future prospects of the investment, as well as the scope of the equation should consider the benefit gained from the corporate and external levels. Today the equation is tied into the market that exists today, and the added value of the investment is evaluated only on a property level.

Through a real options analysis (ROA) for instance, it would possible to find the hidden value from the real estate investments, which would not appear through any traditional equation applied in the property business (Vimpari, 2014). Based on the research made by Vimpari (2014), it seems that the development process of revising the regular investment logic has occurred difficult and slow. Therefore, more research is recommended to focus around the additional ways to define the added value of a smart building. In terms of smart buildings, the value of a smart building in a property level should be possible to be reasoned through the corporate and external levels, where the real value of a smart building seems to be hidden.

References

Aalto University (2018) *Väre inside, One Campus*. Available at: http://onecampus.aalto.fi/vare-inside/ (Accessed: 28 June 2018).

Aalto University Campus & Real Estate (2016) *New Building Väre and Maarintie 13*. Available at: https://aaltocre.fi/en/otaniemi-a-small-city-of-its-own/new-building-vare/ (Accessed: 25 June 2018).

Aalto Yliopisto (2018) *Tutustu kampuksen uusiin rakennuksiin*. Available at: http://www.aalto.fi/fi/about/campus/new_buildings/ (Accessed: 28 June 2018).

Accenture (2011) *Energy-Smart Buildings: Demonstrating how information technology can cut energy use and costs of real estate portfolios*. Available at: http://czgbc.org/energy-smart-buildings-whitepaper.pdf (Accessed: 11 April 2018).

Allen, R. H. (1989) *Real estate investment strategy*. 3. ed. Cincinnati, OH: South-Western, p. 394. ISBN 0538196211.

Van Alstyne, M. W., Parker, G. G. and Choudary, S. P. (2016) ‘Pipelines, Platforms, and the New Rules of Strategy’, *Harvard Business Review*, pp. 54–62. ISSN 00178012.

amending EPBD (2016) *Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Directive 2010/31/EU on the Energy Performance of Buildings*. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1486388428439&uri=CELEX:52016PC0765 (Accessed: 8 May 2018).

APUDG (2008) *Greening UK cities’ buildings: Improving the energy efficiency of our offices, shops and factories*. Available at: www.allparty-urbandevelopment.org.uk (Accessed: 11 July 2018).

Bailey, M. and Smith, M. (2017) *The New Real: Unlocking new gains through smart buildings*, *Charles Russell Speechlys*. Available at: https://s3-eu-west-1.amazonaws.com/assets.henley.ac.uk/legacyUploads/pdf/research/papers-publications/The_New_Real_-_An_executive_summary_101067002_1.pdf (Accessed: 13 April 2018).

Baum, A. E. and Hartzell, D. (2012) *Global property investment: Strategies, structures, decisions*. Chichester, West Sussex, U.K: John Wiley & Sons, Incorporated, p. 577. ISBN 9781444335286.

Bonava (2018) *Parempaa asumista [in Finnish]*. Available at: https://www.bonava.fi/inspiraatio/vinkkeja-asumiseen/parempaa-asumista (Accessed: 26 July 2018).

Bughin, J., LaBerge, L. and Mellbye, A. (2017) *The case for digital reinvention*, *McKinsey & Company*. Available at: https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/the-case-for-digital-reinvention (Accessed: 12 April 2018).

Building Efficiency Initiative (2011) *What is a Smart Building?*, *WRI Ross Center for Sustainable Cities - Building Efficiency Initiative Digital News Article*. Available at: http://www.buildingefficiencyinitiative.org/articles/what-smart-building (Accessed: 27 April 2018).

Canadian Electricity Association (2010) *The Smart Grid: A Pragmatic Approach*. Available at: https://electricity.ca/wp-content/uploads/2017/05/SmartGridpaperEN.pdf (Accessed: 21 May 2018).

CEN and CENELEC (2018) *Smart grids*. Available at: https://www.cencenelec.eu/standards/Sectors/SustainableEnergy/SmartGrids/Pages/default.aspx (Accessed: 21 May 2018).

Clements-Croome, D. J. (1997) 'What do we mean by intelligent buildings?', *Automation in Construction*. Elsevier, 6(5–6), pp. 395–400. Available at: https://www.sciencedirect.com/science/article/pii/S0926580597000186 (Accessed: 2 May 2018).

Dearsley, J. (2017) *SUNDAY PROPTECH REVIEW - 14TH MAY 2017*. Available at: http://www.jamesdearsley.co.uk/sunday-proptech-review-14th-may-2017/ (Accessed: 6 April 2018).

El-hawary, M. E. (2014) 'The Smart Grid—State-of-the-art and Future Trends', *Electric Power Components and Systems*. Taylor & Francis Group, 42(3–4), pp. 239–250. Available at: http://www.tandfonline.com/doi/abs/10.1080/15325008.2013.868558 (Accessed: 11 April 2018).

EPBD (2010) 'Directive 2010/31/EU of the European Parliament and the Council of 19 May 2010 on the Energy Performance of Buildings', *Official Journal of the European Union*, L 153(13–35). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2010.153.01.0013.01.ENG&toc=OJ:L:2010:153:TOC. (Accessed: 27 April 2018).

eQ (2017) *Welcome to invest in eQ Real Estate Funds!* Available at: https://www.eq.fi/fi/funds/news/2017-06-01 (Accessed: 30 May 2018).

European Commission (2016) 'COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT Accompanying the document Proposal for a Directive of the European Parliament and of the Council amending Directive 2010/31/EU on the energy performance of buildings', SWD(414 final). Available at: https://ec.europa.eu/energy/sites/ener/files/documents/1_en_impact_assessment_part1_v3.pdf (Accessed: 20 May 2018).

European Commission (2018) *Buildings*. Available at: https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings (Accessed: 12 April 2018).

European Real Estate Forum (2018) *About Real Estate Investment*. Available at: http://www.europeanrealestateforum.eu/ (Accessed: 30 April 2018).

Falkenbach, H., Lindholm, A.-L. and Schleich, H. (2010) 'Review Articles: Environmental Sustainability: Drivers for the Real Estate Investor', *Journal of Real Estate Literature*, 18(2), pp. 201-223. ISSN 0927-7544.

Formigle, I. (2016) *Real Estate Investment Strategy: Four Categories of Risk & Reward*, *Crowdstreet*. Available at: https://www.crowdstreet.com/real-estate-investment-strategy-risk-reward/ (Accessed: 5 June 2018).

Gartner (2018) *Digitalization*, *IT Glossary*. Available at: https://www.gartner.com/it-glossary/digitalization/ (Accessed: 4 May 2018).

Ghaffarianhoseini, A., Berardi, U., AlWaer, H., Chang, S., Halawa, E., Ghaffarianhoseini, A. and Clements-Croome, D. (2016) 'What is an intelligent building? Analysis of recent interpretations from an international perspective', *Architectural Science Review*. Taylor & Francis, 59(5), pp. 338–357. Available at: http://www.tandfonline.com/doi/full/10.1080/00038628.2015.1079164 (Accessed: 24 April 2018).

Goddard, J. G. and Marcum, B. (2012) *Real estate investment: A value based approach*. New York: Springer, p. 298. ISBN 978-3-642-23526-9.

Halmetoja, E. (2017) *Digitalisaatio tempaa mukaansa myös kiinteistö- ja rakennusalan [in Finnish]*, *Senaatti Properties*. Available at: https://www.senaatti.fi/tyoymparisto/inspiraatio/artikkeli/digitalisaatio-tempaa-mukaansa-myos-kiinteisto-ja-rakennusalan/ (Accessed: 25 April 2018).

Hirsjärvi, S. and Hurme, H. (1982) *Teemahaastattelu [in Finnish]*. 2nd edn. Helsinki: Gaudeamus, p. 144. ISBN 9516623220.

Hirsjärvi, S., Remes, P. and Sajavaara, P. (2007) *Tutki ja kirjoita [in Finnish]*. 13th edn. Helsinki: Tammi, p. 448. ISBN 9512656353.

INREV (2013) *REAL ESTATE AS A LONG-TERM INVESTMENT: The impact of regulatory change on long-term investing strategies and on the real economy*. Amsterdam, p. 29. Available at: https://www.inrev.org/system/files/2013-04/INREV_Real_Estate_as_a_Long-Term_Investment_20130408.pdf (Accessed: 30 April 2018).

INREV (2018a) *Investment Intentions Survey Survey 2018*. Available at: https://www.inrev.org/system/files/2018-01/INREV-Investment-Intentions-Survey-2018-snapshot.pdf (Accessed: 5 June 2018).

INREV (2018b) *What is non-listed real estate*. Available at: https://www.inrev.org/about-non-listed-real-estate (Accessed: 30 May 2018).

INREV and EPRA (2016) *REAL ESTATE in the REAL ECONOMY*. Available at: https://www.inrev.org/library/real-estate-real-economy (Accessed: 11 April 2018).

Iyer, B. and Venkatraman, N. V. (2015) *What Comes After Smart Products.*, *Harvard Business Review Digital Articles*. Available at: https://hbr.org/2015/07/what-comes-after-smart-products (Accessed: 11 April 2018).

Janhunen, E. (2018) *Real estate and construction sector investment logic on smart buildings, Master's Thesis*. Aalto University. Department of Mechanical Engineering.

JLL (2013) *Smart Buildings: High Performance Real Estate*. Available at: http://www.jll.com/GSP/global-sustainability/smart-buildings (Accessed: 13 April 2018).

Kayo, G., Hasan, A. and Siren, K. (2014) 'Energy sharing and matching in different combinations of buildings, CHP capacities and operation strategy', *Energy and Buildings*. Elsevier, 82, pp. 685–695. Available at: https://www.sciencedirect.com/science/article/pii/S0378778814006264?via%3Dihub (Accessed: 21 May 2018).

Keles, C., Karabiber, A., Akcin, M., Kaygusuz, A., Alagoz, B. B. and Gul, O. (2015) 'A smart building power management concept: Smart socket applications with DC distribution', *International Journal of Electrical Power & Energy Systems*. Elsevier, 64, pp. 679–688. Available at: https://www.sciencedirect.com/science/article/pii/S0142061514005195?via%3Dihub (Accessed: 21 May 2018).

Kolokotsa, D. (2016) 'The role of smart grids in the building sector', *Energy and Buildings*. Elsevier, 116, pp. 703–708. Available at: https://www.sciencedirect.com/science/article/pii/S0378778815005447 (Accessed: 11 April 2018).

KPGM (2017) *Bridging the Gap: How the Real Estate Sector can engage with PropTech to bring the built and digital environments together*, *KPMG Global PropTech Survey*. Available at: https://home.kpmg.com/uk/en/home/insights/2017/11/kpmg-global-proptech-survey-2017-bridging-the-gap.html (Accessed: 3 April 2018).

KPMG (2017) *Real Estate in the digital age*. Available at: https://assets.kpmg.com/content/dam/kpmg/se/pdf/komm/2017/se-real-estate-in-the-digital-age-2017.pdf (Accessed: 5 July 2018).

Kroner, W. M. (1997) 'An intelligent and responsive architecture', *Automation in Construction*. Elsevier, 6(5–6), pp. 381–393. Available at: https://www.sciencedirect.com/science/article/pii/S0926580597000174 (Accessed: 2 May 2018).

KTI Finland (2014) *Kiinteistöalan yhteiskunnallinen ja kansantaloudellinen merkitys [in Finnish]*, *RAKLI*. Available at: https://kti.fi/wp-content/uploads/Kiinteistöalan-yhteiskunnallinen-ja-kansantaloudellinen-merkitys-2014.pdf (Accessed: 11 April 2018).

KTI Finland (2017) *KTI Market Review Spring 2017*. Available at: https://kti.fi/wp-content/uploads/post/KTI_markkinakatsaus_K17_en_netti.pdf (Accessed: 17 April 2018).

KTI Finland (2018a) *Kiinteistösijoittaminen [in Finnish]*, *RAKLI*. Available at: http://www.rakli.fi/kiinteistosijoittaminen/kiinteistosijoittaminen.html (Accessed: 1 June 2018).

KTI Finland (2018b) *The Finnish Property Market*. Available at: https://kti.fi/wp-content/uploads/The-Finnish-Property-Market-2018_web.pdf (Accessed: 11 April 2018).

Lecamus, V. (2017) *PropTech: What is it and how to address the new wave of real estate startups?*, *Medium*. Available at: https://medium.com/@vincentlecamus/proptech-what-is-it-and-how-to-address-the-new-wave-of-real-estate-startups-ae9bb52fb128 (Accessed: 8 May 2018).

McKinsey & Company (2015) *Digital America: A tale of the haves and have-mores*. Available at: https://www.mckinsey.com/industries/high-tech/our-insights/digital-america-a-tale-of-the-haves-and-have-mores (Accessed: 3 April 2018).

Nurmi, K. (2018) *Metrokeskuksesta tulee Otaniemen olohuone – 'Varsinkin ravintolat kiinnostuneita' [in Finnish]*, *Länsiväylä Digital Articles*. Available at: https://www.lansivayla.fi/artikkeli/625170-metrokeskuksesta-tulee-otaniemen-olohuone-varsinkin-ravintolat-kiinnostuneita (Accessed: 28 June 2018).

PeerRealty (2016) *From Core to Opportunistic: Real Estate Investing & Risk/Return Profiles*. Available at: https://peerrealty.com/blog/from-core-to-opportunistic-real-estate-investing-and-risk-return-profiles (Accessed: 5 June 2018).

Pivo, G. and Fisher, J. D. (2009) *Investment Returns from Responsible Property Investments: Energy Efficient, Transit-oriented and Urban Regeneration Office Properties in the US from 1998-2008*, *Working Paper*. Available at: http://www.immobilierdurable.eu/images/2128_uploads/Gary_Pivo___Investment_returns_on_RPI.pdf (Accessed: 14 June 2018).

Projektiuutiset (2016) *Otaniemen uusi Väre on yksi suurimmista geoenergiakohteista [in Finnish]*. Available at: http://www.projektiuutiset.fi/otaniemen-uusi-vare-on-yksi-suurimmista-geoenergiakohteista/ (Accessed: 18 April 2018).

Rey García, P. (2018) *Smart Readiness Indicator of Buildings Third Stakeholder Meeting*. Brusssels. Available at: https://smartreadinessindicator.eu/sites/smartreadinessindicator.eu/files/sri_3_stakeholder_meeting_minutes_final.pdf (Accessed: 18 June 2018).

ROTI (2017) *Rakennetun omaisuuden tila 2017 [in Finnish]*. Helsinki. Available at: https://talotekniikka.teknologiateollisuus.fi/sites/lvi-talotekniikka/files/RIL_ROTI2017_web2.pdf (Accessed: 20 July 2018).

SAFA (2013) *Campus 2015*, *Architectural Competitions in Finland*. Available at: https://www.google.fi/search?q=väre+pohjapiirrokset&oq=väre+pohjapiirrokset&aqs=chrome..69i57.3215j0j4&sourceid=chrome&ie=UTF-8 (Accessed: 25 June 2018).

Sanastokeskus TSK (2012) 'Kiinteistöliiketoiminnan sanasto, 2. laitos', *RAKLI*. Helsinki, p. 61. Available at: http://www.rakli.fi/media/toimitilat/kiinteistoliiketoiminnan-sanasto.pdf (Accessed: 13 April 2018).

Säynäjoki, A., Pulkka, L., Säynäjoki, E.-S. and Junnila, S. (2017) 'Data Commercialisation: Extracting Value from Smart Buildings', *Buildings*. Multidisciplinary Digital Publishing Institute, 7(4), p. 104. Available at: http://www.mdpi.com/2075-5309/7/4/104 (Accessed: 11 April 2018).

SFS-EN 15232 (2017) *Energy Performance of Buildings. Energy performance of buildings. Part 1: Impact of Building Automation, Controls and Building Management. Modules M10-4,5,6,7,8,9,10*. Helsinki, p. 107.

SFS-EN 52000 (2017) *Energy performance of buildings. Overarching EPB assessment. Part 1 : General framework and procedures. Rakennusten energiatehokkuus. Yleinen EPB arviointi* . Helsinki, p. 138.

Tuomi, J. and Sarajärvi, A. (2009) *Laadullinen tutkimus ja sisällönanalyysi [in Finnish]*. 5th edn. Helsinki: Tammi, p. 175. ISBN 9513148653.

Verbeke, S. *et al.* (2018) *Support for setting up a Smart Readiness Indicator for buildings and related impact assessment: Second progress report*. Available at: https://smartreadinessindicator.eu/sites/smartreadinessindicator.eu/files/sri_secondprogressreport_final_0.pdf (Accessed: 18 June 2018).

Verbeke, S., Ma, Y., Tichelen, P. Van, Bogaert, S., Strategic, W., Waide, P., Uslar, M. and Schulte, J. (2017) *Support for setting up a Smart Readiness Indicator for buildings and related impact assessment: Interim report*, *European Commission DG Energy*. Available at: https://smartreadinessindicator.eu/sites/smartreadinessindicator.eu/files/sri_for_buildings_interim_report_20171212.pdf (Accessed: 11 April 2018).

Verstas Architects (2013) *Aalto University Väre Building*. Available at: http://verstasarkkitehdit.fi/projects/aalto-university (Accessed: 25 June 2018).

Vimpari, J. (2014) *Is there hidden value in real estate investments? : real options analysis provides rationale to contingent investment decisions*. Aalto University. Department of Real Estate, Planning and Geoinformatics, p. 39.

Vimpari, J. and Junnila, S. (2017) 'Evaluating decentralized energy investments: Spatial value of on-site PV electricity', *Renewable and Sustainable Energy Reviews*. Pergamon, 70, pp. 1217–1222. Available at: https://www.sciencedirect.com/science/article/pii/S1364032116310838 (Accessed: 22 August 2018).

Wouters, P. and Laustsen, J. (2017) *The smartness indicator*, *REHVA Journal*. Available at: https://www.rehva.eu/fileadmin/REHVA_Journal/REHVA_Journal_2017/RJ2/p.19/19-22_RJ1702_WEB.pdf (Accessed: 12 April 2018).

Yin, R. K. (2014) *Case study research : design and methods*. 5th edn. Los Angeles: SAGE, p. 282. ISBN 9781483302003.

List of appendixes

Appendix 1. Streamlined SRI-framework. 3 pages
Appendix 2. Smart readiness assessment of the sub-services in the case building. 3 pages.
Appendix 3. Interview details. 1 page.
Appendix 4. Interview questions. 2 pages

Appendix 1 “Streamlined SRI-framework” (1/3)

Domain	Code	Service (aggregated)	Sub-Service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4	Defined in standards (Y/N)	Standard used	Basis for impacts ascribed to functionality	Usual scale of impact	Degree by which the impact can be ascribed to the functionality	Degree to which the functionality can be determined by inspection
Heating	Heating-1a	Heat control - demand side	Heat emission control	No automatic control	Central automatic control (e.g. central thermostat)	Individual room control (e.g. thermostatic valves, or electronic controller)	Individual room control with communication between controllers and to BACS	Individual room control with communication and presence control	Y	EN 15232	Building energy simulation for EN15232	High	High - taken directly from EN15232	High but levels 3 and 4 are harder to assess
Heating	Heating-1b	Heat control - demand side	Emission control for TABS (heating mode)	No automatic control	Central automatic control	Advanced central automatic control	Advanced central automatic control with intermittent operation and/or room temperature feedback control		Y	EN 15232	Building energy simulation for EN15232	High	High - taken directly from EN15232	Medium but level 2 will be hard to assess
Heating	Heating-1c	Heat control - demand side	Control of distribution network hot water temperature (supply or return) - Similar function can be applied to the control of direct electric heating networks	No automatic control	Outside temperature compensated control	Demand based control			Y	EN 15232	Building energy simulation for EN15232	High	High - taken directly from EN15232	Medium but level 2 will be hard to assess
Heating	Heating-1d	Heat control - demand side	Control of distribution pumps in networks	No automatic control	On off control	Multi-Stage control	Variable speed pump control (pump unit (internal) estimations)	Variable speed pump control (external demand signal)	Y	EN 15232	Building energy simulation for EN15232	Medium	High - taken directly from EN15232	Medium - presence of VSD pumps is evident from inspection but their control algorithms less so
Heating	Heating-1e	Heat control - demand side	Intermittent control of emission and/or distribution - One controller can control different rooms/zones having same occupancy patterns	No automatic control	Automatic control with fixed time program	Automatic control with optimum start/stop	Automatic control with demand evaluation		Y	EN 15232	Building energy simulation for EN15232	High	High - taken directly from EN15232	Low/Medium
Heating	Heating-1f	Heat control - demand side	Thermal Energy Storage (TES) for building heating	Continuous storage operation	2-sensor charging of storage	Load prediction based storage operation			Y	EN 15232	Building energy simulation for EN15232	High	High - taken directly from EN15232	Low/Medium
Heating	Heating-1g	Heat control - demand side	Building preheating control	No automatic control	Program heating schedule in advance	Thermostat self-learning user behavior (presence, setpoint)			N	None	None	NA	NA	Low
Heating	Heating-2a	Control heat production facilities	Heat generator control (for combustion and district heating)	Constant temperature control	Variable temperature control depending on outdoor temperature	Variable temperature control depending on the load (depending on supply water temperature set point)			Y	EN 15232	Building energy simulation for EN15232	High/Medium	High - taken directly from EN15232	Low
Heating	Heating-2b	Control heat production facilities	Heat generator control (for heat pumps)	On/Off-control of heat generator	Multi-stage control of heat generator capacity depending on the load or demand (e.g. on/off of several compressors)	Variable control of heat generator capacity depending on the load or demand (e.g. hot gas bypass, inverter frequency control)			Y	EN 15232	Building energy simulation for EN15232	High/Medium	High - taken directly from EN15232	Medium
Heating	Heating-2c	Control heat production facilities	Sequencing of different heat generators	Priorities only based on running time	Control according to fixed priority list: e.g. heat pump prior to hot water boiler	Control according to dynamic priority list (based on current efficiency and capacity of generators)e.g. solar, geothermal heat, cogeneration plant, fossil fuels)	Control according to dynamic priority list (based on predicted and current load, efficiency and capacity of generators)		Y	EN 15232	Building energy simulation for EN15232	High	High - taken directly from EN15232	Low
Heating	Heating-2d	Control heat production facilities	Heat system control according to external signal (e.g. electricity tariff, gas pricing, load shedding signal etc.)	No automatic control based on external signals	Heat system control according to external signals (price, tariff etc.)	Heat system control according to external signals combined with internal signals (demand, temperature etc.)			N	None	None	NA	NA	Low
Heating	Heating-2e	Control heat production facilities	Heat recovery and heat shifting	Instantaneous use of waste heat or heat shifting	Managed use of waste heat or heat shifting (including charging/discharging TES)				Y	EN 15232	Building energy simulation for EN15232	High/Medium	Medium - taken directly from EN15232	Medium
Domestic hot water	DHW-1a	Control DHW production facilities	Control of DHW storage charging (with direct electric heating or integrated electric heat pump)	Automatic control on / off	Automatic control on / off and scheduled charging enable	Automatic control on / off and scheduled charging enable and multi-sensor storage management			Y	EN 15232	Building energy simulation for EN15232	Medium	High - taken directly from EN15232	Low
Domestic hot water	DHW-1b	Control DHW production facilities	Control of DHW storage charging (using hot water generation)	Automatic control on / off	Automatic control on / off and scheduled charging enable	Automatic on/off control, scheduled charging enable and demand-based supply temperature control or multi-sensor storage management			Y	EN 15232	Building energy simulation for EN15232	Medium	High - taken directly from EN15232	Low
Domestic hot water	DHW-1c	Control DHW production facilities	Control of DHW storage temperature, varying seasonally: with heat generation or integrated electric heating	Manual selected control with charging pump on / off or electric heating	Automatic selected control with charging pump on / off or electric heating and charging time release	Automatic selected control with charging pump on / off or electric heating, charging time release and demand-oriented supply or multi-sensor storage management	Automatic selected control with heat generation, demand-oriented supply and return temperature control or electric heating, charging time release and multi-sensor storage management		Y	EN 15232:2012	Building energy simulation for EN15232	Medium	High - taken directly from EN15232:2012	Low
Domestic hot water	DHW-1d	Control DHW production facilities	Control of DHW storage charging (with solar collector and supplementary heat generation)	Manual selected control of solar energy or heat generation	Automatic control of solar storage charge (Prio. 1) and supplementary storage charge	Automatic control of solar storage charge (Prio. 1) and supplementary storage charge and demand-oriented supply or multi-sensor storage management	Automatic control of solar storage charge (Prio. 1) and supplementary storage charge, demand-oriented supply and return temperature control and multi-sensor storage management		Y	EN 15232	Building energy simulation for EN15232	Medium/High	High - taken directly from EN15232	Low
Domestic hot water	DHW-2	DHW control - demand side	Control of DHW circulation pump	No control	Control with time program				Y	EN 15232	Building energy simulation for EN15232	Low	High - taken directly from EN15232	High/Medium

Appendix 1 “Streamlined SRI-framework” (2/3)

Domain	Code	Service (aggregated)	Sub-Service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4	Defined in standards (Y/N)	Standard used	Basis for impacts ascribed to functionality	Usual scale of impact	Degree by which the impact can be ascribed to the functionality	Degree to which the functionality can be determined by inspection
Cooling	Cooling-1a	Cooling control - demand side	Cooling emission control	No automatic control	Central automatic control: There is only central automatic control acting either on the distribution or on the generation. This can be achieved for example by an outside temperature controller conforming to EN 12098–1 or EN 12098–3	Individual room control: By thermostatic valves or electronic controller	Individual room control with communication: Between controllers and BACS (e.g. scheduler, room temperature setpoint)	Individual room control with communication and occupancy detection: Between controllers and BACS; Demand control/occupancy detection (this function level is usually not applied to any slow reacting cool emission systems with relevant thermal mass, e.g. floor cooling)	Y	EN 15232	Building energy simulation for EN15232	High when cooling is significant	High - taken directly from EN15232	High but levels 3 and 4 are harder to assess
Cooling	Cooling-1b	Cooling control - demand side	Emission control for TABS (cooling mode)	No automatic control	Central automatic control: The central automatic control for a TABS zone (which comprises all rooms which get the same supply water temperature) typically is a supply water temperature control loop whose set-point is dependent on the filtered outside temperature, e.g. the average of the previous 24 h	Advanced central automatic control: This is a central automatic control of the TABS zone that is designed and tuned to achieve an optimal self-regulating of the room temperature within the required comfort range (specified by the room temperature cooling set-point). “Optimal” means that the room temperatures of all rooms of the TABS zone remain during operation periods in the comfort range, to meet comfort requirements, but also is as high as possible to reduce the energy demand for cooling.	Advanced central automatic control with intermittent operation and/or room temperature feedback control:		Y	EN 15232	Building energy simulation for EN15232	High when cooling is significant	High - taken directly from EN15232	Low
Cooling	Cooling-1c	Cooling control - demand side	Control of distribution network chilled water temperature (supply or return)	Constant temperature control	Outside temperature compensated control	Demand based control			Y	EN 15232	Building energy simulation for EN15232	High when cooling is significant	High - taken directly from EN15232	Medium but level 2 will be hard to assess
Cooling	Cooling-1d	Cooling control - demand side	Control of distribution pumps in networks	No automatic control	On off control	Multi-Stage control	Variable speed pump control (pump unit (internal) estimations)	Variable speed pump control (external demand signal)	Y	EN 15232	Building energy simulation for EN15232	Medium	High - taken directly from EN15232	Medium - presence of VSD pumps is evident from inspection but their control algorithms less so
Cooling	Cooling-1e	Cooling control - demand side	Intermittent control of emission and/or distribution	No automatic control	Automatic control with fixed time program	Automatic control with optimum start/stop	Automatic control with demand evaluation		Y	EN 15232	Building energy simulation for EN15232	High when cooling is significant	High - taken directly from EN15232	Low/Medium
Cooling	Cooling-1f	Cooling control - demand side	Interlock between heating and cooling control of emission and/or distribution	No interlock	Partial interlock (dependant of the HVAC system)	Total interlock			Y	EN 15232	Building energy simulation for EN15232	High when cooling is significant	High - taken directly from EN15232	Medium
Cooling	Cooling-1g	Cooling control - demand side	Control of Thermal Energy Storage (TES) operation	Continuous storage operation	Time-scheduled storage operation	Load prediction based storage operation			Y	EN 15232	Building energy simulation for EN15232	High when cooling is significant	High - taken directly from EN15232	Low/Medium
Cooling	Cooling-2a	Control cooling production facilities	Generator control for cooling	Constant temperature control	Variable temperature control depending on outdoor temperature	Variable temperature control depending on the load			Y	EN 15232	Building energy simulation for EN15232	High when cooling is significant	High - taken directly from EN15232	Low
Cooling	Cooling-2b	Control cooling production facilities	Sequencing of different cooling generators	Priorities only based on running times	Priorities only based on loads	Priorities based on generator efficiency and characteristics	Load prediction based sequencing		Y	EN 15232	Building energy simulation for EN15232	High when cooling is significant	High - taken directly from EN15232	Low
Mechanical ventilation	MV-1a	Air flow control	Supply air flow control at the room level	No automatic control	Time control	Occupancy Detection			Y	EN 15232	Building energy simulation for EN15232	Medium when ventilation is significant	High - taken directly from EN15232	Medium
Mechanical ventilation	MV-1b	Air flow control	Adjust the outdoor air flow rate	Fixed OA ratio / OA flow	Staged (low/high) OA ratio / OA flow (time schedule)	Staged (low/high) OA ratio / OA flow (presence)	Variable control		Y	EN 15232	Building energy simulation for EN15232	Medium-Low when ventilation is significant	High - taken directly from EN15232	Low
Mechanical ventilation	MV-1c	Air flow control	Air flow or pressure control at the air handler level	No automatic control	On off time control	Multi-stage control	Automatic flow or pressure control (without reset)	Automatic flow or pressure control (with reset)	Y	EN 15232	Building energy simulation for EN15232	Medium when ventilation is significant	High - taken directly from EN15232	Low
Mechanical ventilation	MV-2a	Air temperature control	Room air temp. control (all-air systems)	on-off capacity control	variable capacity control	Demand control			Y	EN 15232	Building energy simulation for EN15232	Medium when ventilation is significant	High - taken directly from EN15232	Medium
Mechanical ventilation	MV-2b	Air temperature control	Room air temp. control (Combined air-water systems)	No coordination	Coordination				Y	EN 15232	Building energy simulation for EN15232	Medium when ventilation is significant	High - taken directly from EN15232	Medium
Mechanical ventilation	MV-2c	Air temperature control	Heat recovery control: prevention of overheating	Without overheating control	With overheating control				Y	EN 15232	Building energy simulation for EN15232	Medium when ventilation is significant	High - taken directly from EN15232	Medium/Low
Mechanical ventilation	MV-2d	Air temperature control	Supply air temperature control	No automatic control	Constant set point	Variable set point with outdoor temperature compensation	Variable set point with load dependant compensation		Y	EN 15232	Building energy simulation for EN15232	Medium when ventilation is significant	High - taken directly from EN15232	Medium but level 3 will be hard to assess
Mechanical ventilation	MV-3	Free cooling	Free cooling	No automatic control	Night cooling	Free cooling	H,x- directed control		Y	EN 15232	Building energy simulation for EN15232	Medium when ventilation is significant	High - taken directly from EN15232	Low

Appendix 1 “Streamlined SRI-framework” (3/3)

Domain	Code	Service (aggregated)	Sub-Service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4	Defined in standards (Y/N)	Standard used	Basis for impacts ascribed to functionality	Usual scale of impact	Degree by which the impact can be ascribed to the functionality	Degree to which the functionality can be determined by inspection
Lighting	Lighting-1a	Artificial lighting control	Occupancy control for indoor lighting	Manual on/off switch	Manual on/off switch + additional sweeping extinction signal	Automatic detection (auto on / dimmed or auto off)	Automatic detection (manual on / dimmed or auto off)		Y	EN 15232	Building energy simulation for EN15232	Medium when lighting is significant	High - taken directly from EN15232	High
Lighting	Lighting-2	Control artificial lighting power based on daylight levels	Control artificial lighting power based on daylight levels	Manual (central)	Manual (per room / zone)	Automatic switching	Automatic dimming		Y	EN 15232	Building energy simulation for EN15232	Medium when lighting is significant	High - taken directly from EN15232	High
Dynamic building envelope	DE-1	Window control	Window blind control	Manual operation	Motorized operation with manual control	Motorized operation with automatic control	Combined light/blind/HVAC control	Predictive blind control	Y	EN 15232	Building energy simulation for EN15232	High when cooling is significant and glazing areas high.	High - taken directly from EN15232	Medium/High
Energy generation	EG-5	Local energy production and renewable energies	Local energy production and renewable energies	Uncontrolled generation depending on the fluctuating availability of RES and or run time of CHP; overproduction will be fed into the grid	Coordination of local RES and CHP with regard to local energy demand profile including energy storage management; Optimization of own consumption				Y	EN15232	Building energy simulation for EN15232	Medium/High	High - taken directly from EN15232	Medium/High
Demand side management	DSM-18	Smart Grid Integration	Smart Grid Integration	None - No harmonization between grid and buildi	Building energy systems are managed and operated depending on grid load; demand side management is used for load shifting				Y	EN15232	Simulation	Medium/High	Medium	Medium
Demand side management	DSM-19	DSM control of equipment	DSM control of equipment	Not present	Smart appliances subject to DSM control	DHW subject to DSM control	Heating subject to DSM control	Heating and cooling subject to DSM control	N	None	None	Medium/High	Medium	Medium
Electric vehicle charging	EV-15	EV Charging	Charging	Not present	Low charging capacity	Medium charging capacity	High charging capacity		N	None	None	High	High	High
Electric vehicle charging	EV-16	EV Charging - Grid	Grid balancing	Not present	1 way (controlled charging)	2 way (also EV to grid)			N	None	None	High	Medium/High	Medium
Monitoring and control	MC-1	HVAC interaction control	Heating and cooling set point management	Manual setting room by room individually	Adaptation from distributed / decentralized plant rooms only	Adaptation from a central room	Adaptation from a central room with frequent set back of user inputs		Y	EN 15232	Building energy simulation for EN15232	Medium/High	High - taken directly from EN15232	Medium
Monitoring and control	MC-2 non-residential only	HVAC interaction control	Energy (Heat, Cold) exchange/management among zones within one building or among different buildings						N	None	None	Medium	Very low	Low
Monitoring and control	MC-3	HVAC interaction control	Run time management of HVAC systems	Manual setting (plant enabling)	Individual setting following a predefined time schedule including fixed preconditioning phases	Individual setting following a predefined time schedule; adaptation from a central room; variable preconditioning phases			Y	EN 15232	Building energy simulation for EN15232	Medium	High - taken directly from EN15232	Medium
Monitoring and control	MC-4	Fault detection	Detecting faults of technical building systems and providing support to the diagnosis of these faults	No central indication of detected faults and alarms	With central indication of detected faults and alarms	With central indication of detected faults and alarms / diagnosing functions			Y	EN 15232	Building energy simulation for EN15232	Medium	High - taken directly from EN15232	High
Monitoring and control	MC-5	Feedback - Reporting information	Reporting information regarding current energy consumption	None	Indication of actual values only (e.g. temperatures, meter values)	Trending functions and consumption determination	Analysing, performance evaluation, benchmarking		Y	EN 15232	Building energy simulation for EN15232	Medium	High - taken directly from EN15232	High
Monitoring and control	MC-6	Feedback - Reporting information	Reporting information regarding historical energy consumption	None	Indication of actual values only (e.g. temperatures, meter values)	Trending functions and consumption determination	Analysing, performance evaluation, benchmarking		N	None	None	Medium	Low	High
Monitoring and control	MC-7	Feedback - Reporting information	Reporting information regarding predicted energy consumption	None	Indication of actual values only (e.g. temperatures, meter values)	Trending functions and consumption determination	Analysing, performance evaluation, benchmarking		N	None	None	Medium	Low	High
Monitoring and control	MC-8 residential with boiler only	Feedback - Reporting information	Reporting information regarding IAQ	No CO detector	CO detector				N	None	None	Medium	High	High
Monitoring and control	MC-8 non-residential	Feedback - Reporting information	Reporting information regarding IAQ	Only temperature reporting	Air quality sensors (e.g. CO2) and central monitoring	Analysing, performance evaluation, benchmarking			N	None	None	Medium	Low	High
Monitoring and control	MC-9R	Remote control and inoccupancy defaults (SFH/MFH)	Remote control and inoccupancy defaults (SFH/MFH)	Not present	Remote control of main TBS	Remote control of main TBS with centralised occupancy detection	Remote control of main TBS with centralised occupancy detection, automatic non-occupancy default settings and user alerts		N	None	None	Medium	Low	High

Appendix 2 “Smart readiness assessment of the sub-services in the case building” (1/3)

Code	Sub-Service	Nominal functionality level	Maximum functionality level
	Heating-1 Heat control on the demand side		
Heating-1a	Heat emission control	3	4
Heating-1b	Emission control for TABS (heating mode)	2	3
Heating-1c	Control of distribution network hot water temperature (supply or return) - Similar function can be applied to the control of direct electric heating networks	2	2
Heating-1d	Control of distribution pumps in networks	3	4
Heating-1e	Intermittent control of emission and/or distribution - One controller can control different rooms/zones having same occupancy patterns	2	3
Heating-1f	Thermal Energy Storage (TES) for building heating	0	2
Heating-1g	Building preheating control	1	2
	Heating-2 Heat control on the supply side		
Heating-2a	Heat generator control (for combustion and district heating)	1	2
Heating-2b	Heat generator control (for heat pumps)	2	2
Heating-2c	Sequencing of different heat generators	3	3
Heating-2d	Heat system control according to external signal (e.g. electricity tariff, gas pricing, load shedding signal etc.)	0	2
Heating-2e	Heat recovery and heat shifting	0	1
SUM		**19**	**30**
DHW-1a	Control of DHW storage charging (with direct electric heating or integrated electric heat pump)	0	0
DHW-1b	Control of DHW storage charging (using hot water generation)	0	0
DHW-1c	Control of DHW storage temperature, varying seasonally: with heat generation or integrated electric heating	0	0
DHW-1d	Control of DHW storage charging (with solar collector and supplementary heat generation)	0	0
DHW-2	Control of DHW circulation pump	0	1
SUM		**0**	**1**

Appendix 2 “Smart readiness assessment of the sub-services in the case building” (2/3)

Cooling-1 Cooling control on the demand side			
Cooling-1a	Cooling emission control	4	4
Cooling-1b	Emission control for TABS (cooling mode)	1	3
Cooling-1c	Control of distribution network chilled water temperature (supply or return)	0	2
Cooling-1d	Control of distribution pumps in networks	4	4
Cooling-1e	Intermittent control of emission and/or distribution	0	3
Cooling-1f	Interlock between heating and cooling control of emission and/or distribution	2	2
Cooling-1g	Control of Thermal Energy Storage (TES) operation	0	2
Cooling-2 Cooling control on the supply side			
Cooling-2a	Generator control for cooling	0	2
Cooling-2b	Sequencing of different cooling generators	1	3
SUM		**12**	**25**
MV-1 Air Flow Control			
MV-1a	Supply air flow control at the room level	2	2
MV-1b	Adjust the outdoor air flow rate	2	3
MV-1c	Air flow or pressure control at the air handler level	2	4
MV-2 Air Temperature Control			
MV-2a	Room air temp. control (all-air systems)	2	2
MV-2b	Room air temp. control (Combined air-water systems)	1	1
MV-2c	Heat recovery control: prevention of overheating	1	1
MV-2d	Supply air temperature control	2	3
MV-3	Free cooling	2	3
SUM		**14**	**19**
Lighting-1a	Occupancy control for indoor lighting	3	3
Lighting-2	Control artificial lighting power based on daylight levels	3	3
SUM		**6**	**6**
DE-1	Window blind control	**2**	**4**
EG-5	Local energy production and renewable energies	**0**	**1**
DSM-18	Smart Grid Integration	0	1
DSM-19	DSM control of equipment	0	4
SUM		**0**	**5**

Appendix 2 “Smart readiness assessment of the sub-services in the case building” (3/3)

MC-1	Heating and cooling set point management	3	3	1
MC-2 non-residential only	Energy (Heat, Cold) exchange/management among zones within one building or among different buildings	0	0	NA
MC-3	Run time management of HVAC systems	2	2	1
MC-4	Detecting faults of technical building systems and providing support to the diagnosis of these faults	0	2	0
MC-5	Reporting information regarding current energy consumption	2	3	0,67
MC-6	Reporting information regarding historical energy consumption	2	3	0,67
MC-7	Reporting information regarding predicted energy consumption	0	3	0
MC-8 residential with boiler only	Reporting information regarding IAQ	0	0	NA
MC-8 non-residential	Reporting information regarding IAQ	1	2	0,5
MC-9R	Remote control and inoccupancy defaults (SFH/MFH)	0	0	NA
SUM		**10**	**18**	**3,83**

Information about the interviewees, interviewing times and places

1. Aalto University Campus and Real Estate (ACRE)

   Eetu Ristaniemi; Director, Real Estate Investments

   Interviewing time and place: 28.5.2018, K1-building, Otakaari 4, 02150 Espoo

2. SRV

   Joni Jumisko; Project Manager, Building Services

   Interviewing time and place: 8.6.2018, Derby Business Park, Tarvonsalmenkatu 13-19, 02600 Espoo

3. JLL

   Tero Lehtonen; National Director, Head of Advisory

   Interviewing time and place: 11.6.2018, World Trade Centre (WTC) building, Aleksanterinkatu 17, 00100 Helsinki

4. Aalto University, Grandlund

   Heikki Ihasalo; Professor of Practice in Smart Building Technologies and Services (Aalto Unversity); Senior Consultant, Building Automation (Grandlund)

   Interviewing time and place: 19.6.2018, TUAS-building, Maarintie 8, 02150 Espoo

5. Bonava

   Matti Kuronen; Regional Manager

   Interviewing time and place: 25.7.2018, Sanomatalo, Töölönlahdenkatu 2, 00100 Helsinki

6. Skanska

   Miro Ristimäki; Development Manager, Head of BIM team and Digital Services

   Interviewing time and place: 15.8.2018, Skanskatalo, Nauvontie 18, 00280 Helsinki

Interview questions (Finnish)

1. Kiinteistösijoitusstrategia
    a) Millainen on yrityksenne kiinteistöliiketoiminta/sijoitusstrategia?

2. Älykkään rakennuksen määritelmä
    a) Millainen on älykäs rakennus teidän mielestänne?

3. Älykkään rakennuksen investointilogiikka
    a) Miten kiinteistönomistaja pystyy perustelemaan älykkään rakennuksen alkuinvestoinnin?
        - Tuottovaatimus
        - Vuokrataso
        - Täyttöaste
        - Sopimuksen mitta
        - Kustannukset
            - Ylläpito
            - Kunnossapito

4. Smart readiness indicator
    a) Millaisena SRI näyttäytyy kiinteistötoimijan näkökulmasta?
    b) Miten SRI vertautuu näkemyksenne mukaan esimerkiksi ympäristösertifikaatti LEED:n kanssa?

5. Monikäyttöisen kampusrakennuksen ominaisuudet (vain kampusrakennuksen yritys edustajat)
    a) Millaiseksi kampusrakennusta alun perin suunniteltiin, ja miten se toteutui käytännössä?

Interview questions (English)

1. Real estate investment strategy
   a) What kind of real estate business/investment strategy the company your represent follows?

2. Definition of a smart building
   a) What features does a smart building has in your opinion?

3. Investment logic on smart buildings
   a) How a property owner can validate an initial investment on a smart building?
      - Required yield
      - Rent level
      - Vacancy rate
      - Length of the contact
      - Expenses
        - Costs of operations
        - Costs of repairs and replacements

4. Smart readiness indicator
   a) How does SRI appear from the real estate specialist’s point of view?
   b) How is SRI comparable with the environmental certificate LEED, for instance, in your opinion?

5. The characteristics of the multi-purpose campus building (only the representatives of the campus building)
   a) How was the original design of the multi-purpose campus building, and how was it realised in practice?